APRIL 1961

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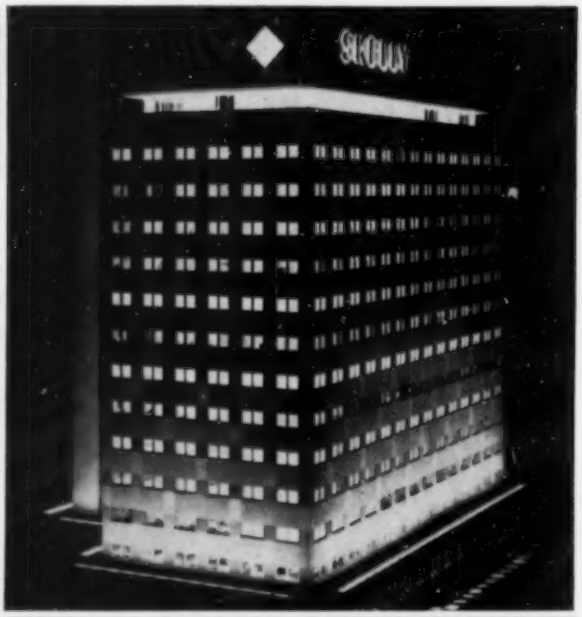
ILLUMINATING ENGINEERING

Journal of the
ILLUMINATING ENGINEERING SOCIETY

Beautiful Lighting for a Beautiful Building



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THE JOURNAL OF THE ILLUMINATING ENGINEERING SOCIETY

April
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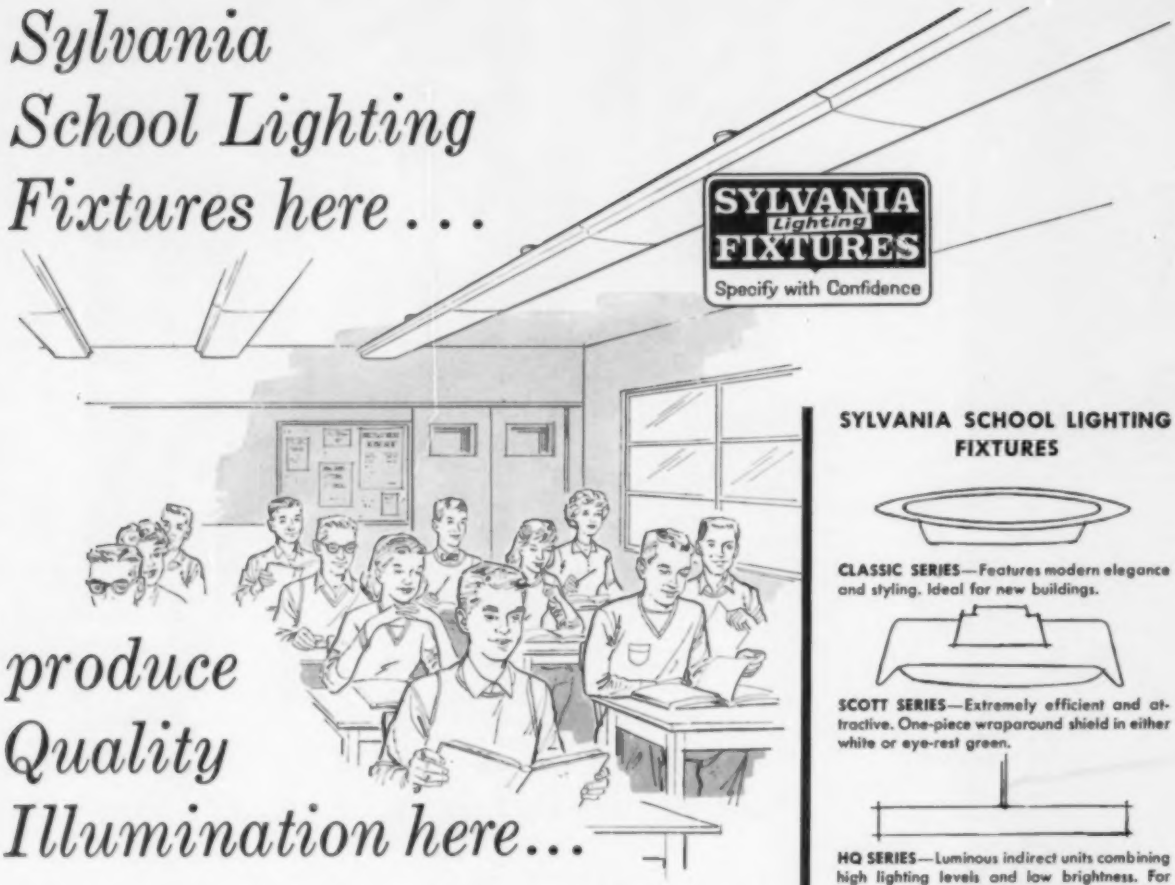

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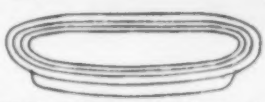

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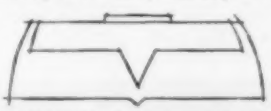

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Cove Lighting In a Library

To a lighting profession approaching maturity in terms of scientific aspects of illumination, modern architectural design poses a complete new set of problems. The exciting building shapes which delight the esthetically minded have become a problem to engineers accustomed to designing lighting for ceiling mounting. The solution of these problems demands imaginative concepts — sometimes the development of a new technique or, as in the present case, use of a standard technique in a new guise. This library lighting design resulted in the development of a new simplified empirical formula for point by point calculation of illumination on the ceiling, then on the work surface, using a line source.

By M. G. TALBOT

COVE LIGHTING, long a standard for creating "atmosphere," has found a new application —as a general lighting system in buildings where varied ceiling heights or shallow roof construction prevent the use of recessed or surface mounted equipment. March IE reported the application of industrial fixtures in coves for the general lighting (to 35 footcandles) of a church with a steep sloping roof. The installation described here demonstrates the application of three-lamp industrial fixtures in a cove to provide an average maintained level of 70 footcandles in a domed ceiling library.

The library of Pacific High School in San Leandro, Calif., is situated atop the circular section of the school building, its floor lying between the first and second stories of the building and the roof rising above the second story. The room is circular in cross section with a diameter of 60 feet and is topped by a parabolic ceiling-roof of four-inch-thick prestressed concrete. Ceiling heights range from 17 feet in the center of the library to 14 feet at the edges. The room is encircled by large clerestory windows fitted with a special opaque glass incorporating small, closely knit, built-in louvers which reflect daylight outward and light back into the room. To facilitate lighting design, since no fixtures could be mounted on the thin concrete roof, a cove was designed around the entire circumference of the library, above the seven-foot-high bookcases.

Lighting design level at the time the building was being planned (1957) was set at 70 footcandles, far in excess of then current IES recommended levels and even now meeting the recommendation for a library reading room. First lighting plan for the area employed ten 500-watt PAR-64 lamps with a maximum beam candlepower of 35,000 for every 18-degree ceiling sector. Lamps were aimed for even coverage of the diametrically

AUTHOR: Commercial Lighting Representative, Pacific Gas & Electric Co., Hayward, Calif. Architect, Schmidts, Hardman, Wong, Berkeley, Calif.; Consulting Engineer, Stanley Johnson.
This installation won first prize in the Diablo Section's 1960 Applied Lighting Competition and second prize in the South Pacific Coast Regional Competition.

Figure 3. Close-up showing luminaire mounting in cove.

opposite 18-degree ceiling sectors and the other side of the room.

Point by point calculation of the illumination results, including an 80 per cent ceiling reflection factor, revealed the inefficiency of this system. Lighting levels varied from 125 footcandles at the center of the room to 30 footcandles at the edges, without inclusion of a maintenance factor. In addition, the load for the system was over 100 kw, far in excess for the room's physical size.

A second lighting design used four-foot two-lamp 1500-ma fluorescent industrial fixtures mounted at an angle upside down within the cove. Late in 1957 when calculations were made, the 1500-ma lamps had recently been reintroduced and their average output rated at 2.46 times that of the four-foot 430-ma lamps. Thus, all of the corresponding calculations were based on these figures. A fixture reflector type was chosen and corresponding curves were used times a factor of 2.46.

Initial calculations for this system, based on the method outlined in the *IES Lighting Handbook*, Second Edition, indicated that with a maintenance factor included, lighting level would fall below the desired 70 footcandles. A second set of calculations was made following a method outlined in an article by Robert E. Burnham ("The Illumination at a Point from an Industrial Fluorescent Luminaire," December 1950 ILLUMINATING ENGINEERING, p. 753). Burnham's derivation was complete and correct but involved certain basic assumptions for the derivation of the formula. As he noted in the article, however, a physical error is often encountered when assumptions are made, and with the advent of the 1500-ma lamp (the non-circular cross section lamp in particular) the derived equations became even more questionable as to the amount of error.

Following a considerable number of physical tests, under nearly ideal laboratory conditions, on both two- and three-lamp 1500-ma industrial fixtures equipped with both circular and non-circular cross section lamps, a curve (Fig. 4) was plotted for Burnham's values K and $H = 0$. A simplified version of Burnham's formulas, an empirical formula based on observed physical data, was derived:

$$Ep = Cp \times K \times \cos\theta$$

where Ep = illumination at a point P measured in footcandles,

Cp = candlepower of the fixture at the angle subtended from the center of the fixture to point P,

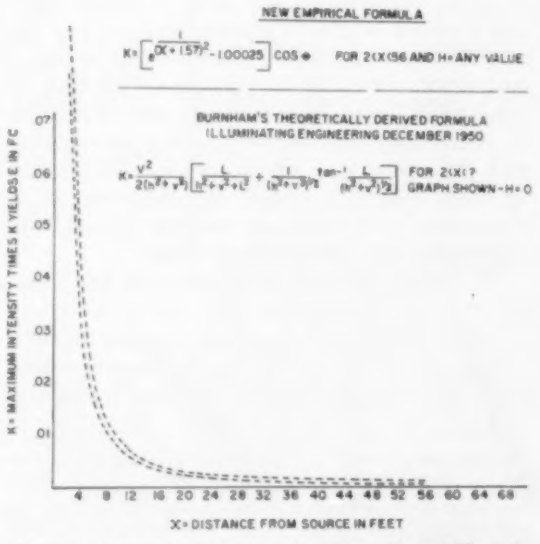
$$K = \left[\frac{1}{e^{\frac{1}{(x+1.57)^2}}} - 1.00025 \right]$$

where $e = 2.71828$

x = distance measured from the center of the fixture to the point P in feet

$\cos\theta$ = angle subtended by the normal to the plane at point P and the line extending from the center of the fixture to point P.

Practical limits: $2 < x < 55$ feet.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FOR 2≤X≤? GRAPH SHOWN - H=0
K = MAXIMUM INTENSITY TIMES K YIELDS E IN FC
07
06
05
04
03
02
01
4 8 12 16 20 24 28 32 36 40 44 48 52 56 60 64 68
X = DISTANCE FROM SOURCE IN FEET

Figure 4. Curve for Burnham's values K and $H = 0$.

Although the initial curve was plotted for $H = 0$, this general formula may be applied to any value of H because it uses the actual candlepower value at the working angle rather than the maximum candlepower per foot factor used by Burnham. From the candlepower distribution curves supplied by manufacturers and the fact that the distance factor and angles may be obtained graphically, this empirical formula may be used for obtaining fast and accurate results.

Like any empirical formula, however, this one has its limitations. At a distance of about 60 feet the value of 1.00025 approaches $e^{\frac{1}{(x + 1.57)^2}}$ and the equation approaches zero or even a negative number. For practical purposes, however, the footcandle values obtained from the 1500-ma fluorescent fixture at a distance of 55 feet or more are so small that they may be neglected. In an installation where a number of these fixtures are used at distances greater than 55 feet, the use of the lumen method would, undoubtedly, be advantageous.

Using this empirical formula, a new set of calculations was made to find the illumination on the library ceiling from a three-lamp, 48-inch, 1500-ma industrial fixture. (A time saving factor of about 5 to 1 was observed with the use of this method.) The calculation procedure used was as follows:

(1) Since the room is symmetrical, it may be cut in half.

(2) Find the distances and the angles from each four-foot fixture to the desired ceiling point.

(3) Apply the formula to each fixture on the half of the room selected.

(4) Add the components calculated for half of the room.

(5) Double the figure obtained in (4) to obtain the total illumination incident on the ceiling at that point. This may be done because of the symmetry of the room.

(6) Subtract 20 per cent of the figure obtained in (5) for absorption.

(7) Consider the ceiling as the light source and obtain an average value.

(8) To obtain the illumination at a point on the working surface apply the formula

$fc = \frac{1}{2}$ (source brightness in fL) $\times$ $(1 - \cos \theta)$.* Since all angles in this case are greater than 90 degrees, $\cos \theta$ is negative and the expression becomes

$fc = \frac{1}{2}$ (source brightness in fL) $\times$ $(1 + \cos \theta)$. The working surface is considered to be 30 inches above the floor.

(9) Multiply the value obtained in (8) by a maintenance factor.

With the procedure outlined above, the illumination level may be obtained for any point in the room. The values obtained will be minimum due to the fact that all interreflectances are neglected.

The following values were obtained for the illumination on the working surfaces at the Pacific High School library. Refer to Fig. 5: Section 1—60 footcandles; II—59.6; III—59.8; IV—66.7; V—78.6; VI—52.6. After this final set of calculations was made, the lighting design was altered to employ three-lamp, eight-foot industrial fixtures of the same type, but this did not alter the calculated values appreciably.

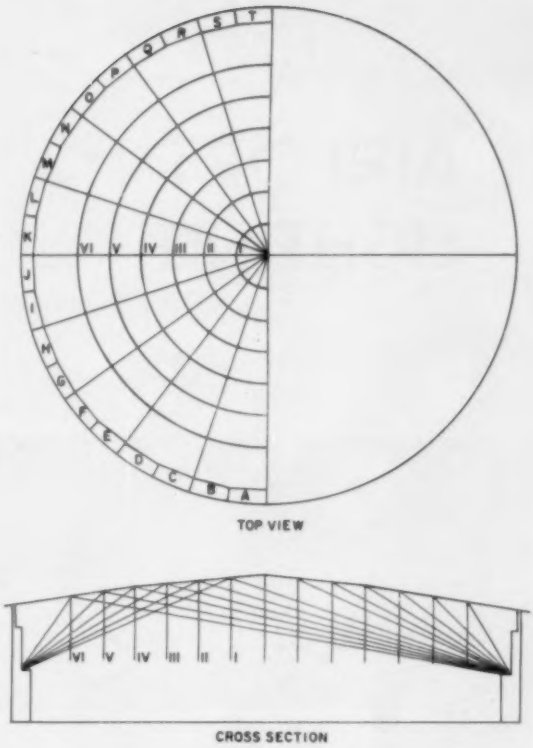

Figure 5.

The formula presented here should greatly accelerate and simplify lighting design with line sources. It is important to remember, however, that the formula is empirical and observed practical limits are between 2 and 55 feet. Maximum errors encountered are approximately 3.5 per cent and average less than 1 per cent. The formula is based on the 1500-ma industrial type fixture and although it may hold true for other fixture types and wattages, no claims are being made at present.

The cove lighting system designed with the aid of this formula provided an average maintained level of 70 footcandles in the library with surface reflectances of walls, 45 per cent; floor, 30 per cent and ceiling, 80 per cent. The cove technique has been found to provide an excellent source for high quality general illumination when used with a fixture incorporating the proper reflector. The system can compete favorably with a luminous indirect design, considered by many to provide the highest quality lighting.

IES Lighting Handbook, Third Edition, p. A-24.

Public Face of

AIRPORT LIGHTING

However vital runway, taxiway and other landing aid lighting systems are to the functioning of an airport, they are only part of the lighting story. Illumination design for the public face of the airport (terminal and administration building) presents problems akin to those of any public area—restaurants, lobbies, display rooms, etc. Lighting for Deer Valley Airport, by William B. Keller, Keller Engineering Co., Phoenix, was functionally planned to preserve the architectural design of the administration building. Some of the areas are shown here.

Administration building of Deer Valley Airport, a private facility in Phoenix, Ariz., is a long, low, sweeping structure designed to reflect the mood of the southwest desert landscape. Dominant interior architectural elements are structural supporting members for roof, 5- by 27- by 36-inch "gluelam" beams stained a deep tone.

Dignified atmosphere of T-shaped lobby is enhanced by six custom-designed lighting units, each 5 feet 3½ inches wide by 8 feet ¾ inch long, mounted between dark structural beams of the ceiling. Units use four F96T12 cool white lamps in strip mounting on 15-inch centers, with ½-inch cell plastic louver material installed 12 inches below the lamps. Translucent plastic ends on fixtures reduce contrast between lighted areas and white ceiling sections between beams. Maintained lighting level here is 43 fc. A decorative lighting element is supplied by two R40 150-watt floods in adjustable bullet units used to display texture of stone panel.

Row of pendant mounted satin opal glass fixtures with 60-watt incandescent lamps combined with a row of perforated cone-shaped fixtures using 150-watt R40 lamps provide pleasant lighting atmosphere in airport restaurant. Lighting level along window wall under pendant units is 18 fc, rising to 25 fc under the row of R40 fixtures. Inner row of R40 units also acts as corridor lighting to airplane display area and provides a transition between the subdued restaurant atmosphere and the higher lighting levels in the adjacent snack bar (not shown). Five R40 150-watt lamps in adjustable fixtures in front of the open block wall room divider can be used to provide either even light distribution over the wall or highlighting on picture displays.

In the classroom/ready room, the air conditioning contractor usurped the space intended for recessed lighting and forced the installation of shallow, two-lamp, 40-watt, rapid-start luminaires with glass sides and low brightness bottom panels. Lighting levels are 50 fc in the high-ceilinged area, where fixtures are mounted between structural beams, and 85 fc in the dropped ceiling area.

Airplane display and sales center is a 42- by 40-foot area with two open sides, architecturally dominated by the 1 foot 8 inch "gluelam" beams supporting the observation deck above. Subtle lighting, from nine adjustable twin downlights using one 150-watt R40 spot and one 150-watt R40 flood, is concealed by the beams. This lighting system produces an average of 20 fc in the display area with good coverage on the horizontal surfaces of the planes and no harsh shadows on the concrete floor. The flexible lighting design in this area is suitable to the effective display of most of the private planes which are being manufactured today.

A.I.A. File No. 31*f*

INSTALLATION AT COLLECTION OFFICE OF WEST PENN POWER CO., CHARLEROI, PA.

Lighting a Collection Office

LIGHTING OBJECTIVE: To provide general and supplementary illumination for regular office work, including tabulating and ink and pencil handwriting, in the customer service area of a collection office.

GENERAL INFORMATION: The customer service area shown above measures approximately 13 feet in width, 15 feet in length, and 9 feet in ceiling height (to plastic panels). Colors and reflectances of the major room surfaces are:

walls			ceiling plenum	white	90%
rear and right	blue	40%	floor	tan	30%
left	tan	55%	desk & counter top	white	80%

INSTALLATION: General illumination is provided by Sylvania Electric Products Inc. catalog No. CS-27212-IS two-lamp surface mounted wiring channel luminaires installed above the Sylvania Sylva-Lume shallow panel white vinyl plastic ceiling. Luminaires are mounted in tandem across the room (for a 12-foot run) and are spaced on 15-inch centers down the length, for a total of 22 units in the customer service area. Each unit is equipped with two 72-inch T-12 cool white slimline fluorescent lamps.

Supplementary lighting is provided at the wall counter (at left in photo above) by seven General Lighting Co. catalog No. 1006 wall-mounted incandescent units spaced on two-foot centers. Each unit is equipped with one 150-watt PAR flood lamp.

After one year's continuous operation the illumination levels were 150 footcandles at the collection counter and 170 footcandles at the customer wall counter. Brightnesses at that time were: luminous ceiling at 60 degrees, 200 fL; floor, 35 fL and desk top, 80 fL.

Lighting designed by Hoffman & Crumpton, Century Building, Pittsburgh, Pa.

Lighting data submitted by W. E. Layton, West Penn Power Co., Charleroi, Pa., as an example of good lighting practice and to aid in the design of similar installations.

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Series XXV
4-61

A.I.A. File No. 31*f*

Figure 1. Mercury—in Holland—for 3 to 6 footcandles from HPL 400-watt, 18,000-lumen lamps, four to a pole, mounted at approximately 49 feet (15 meters).

Street lighting engineers the world over have a common objective — easier, safer seeing on the road at night. The European approach as to how this is achieved and what other factors are important or different from U. S. practice is the subject of this review — by an author considered an expert on both sides of the ocean.

EUROPE'S Streets and Highways

By JOHN W. YOUNG

STREET LIGHTING is street lighting, one might think, and if its practice differs from one country to another, these differences must be so minor as to have small interest. Actually, the different *approach* to street and highway lighting in Europe is quite fascinating — not only to street lighting engineers, but to the touristing American traveler as well.

The term "luminous environment" seems scarcely one to apply to street lighting. In Europe, however, this element is given serious consideration in the over-all street lighting plan. As with street lighting engineers the world over, of course, the primary objective is toward improved visibility for the motorist, and much study is being done for the advancement of lighting techniques. Quite noticeable in European countries, however, is an almost inborn desire for attractive appearance—and the development of what can only be described as "luminous environment." Frequently where the functional need has been supplied, still further lighting effects are built in to enhance streets and surroundings. Such supplementary lighting includes high intensity lighting of plazas and squares, and the floodlighting of building facades, distinguished architecture and monuments along the street.

To the traveler using the streets and roadways abroad comes a realization of the value placed on lighting in these countries—a consciousness of the prevalent problems, and an urgency to provide even more adequate and effective lighting.

Trends in Light Sources

This progress in lighting is a projection, in a way, of the advent of the electric discharge lamp—mercury, fluorescent, sodium and xenon sources. The several and various characteristics of these lamps figure importantly in their appropriateness and usefulness. Lamp efficiency, color attributes and high lumen ratings are all conducive to meeting illumination needs of diversified vehicular and pedestrian public ways. In public lighting in Europe these sources are not only superseding but almost completely displacing the familiar incandescent lamp.

Mercury

To the visitor abroad, especially one aware of street lighting trends, there seems to be a strong leaning to, and even preference for, mercury lighting in many European countries. The compactness of this source, and its high luminous efficiency

AUTHOR: Consulting Engineer for Street and Highway Lighting, Boston, Mass.

Figure 2 (left). Brussels — the entire square is lighted by these two high-mounted fluorescent units.

Figure 3 (below). Fluorescent in Holland. Poles are mounted on the buildings and extend out over the center of the street. Note also the illuminated sidewalk showcases.

Figure 4 (facing page, top). Xenon in Germany. Three 20,000-watt xenon and six 400-watt mercury lamps mounted on a 95-foot pole illuminate Munich's whole town square to about 10 footcandles.

Figure 5 (facing page, below). Sodium in Holland. Two 85-watt lamps in each mast on each side of dual-traffic road; two 140-watt lamps at the crossing.

(lu/w) compared with the incandescent lamp has apparently offered the advantage of economy in supplying the higher lighting levels required. Undoubtedly also, the now favorable color properties of the mercury fluorescent types have been an influential factor in the choice of this source.

In its application, the size and type of mercury lamp varies with the types of streets in which it is used, and the nature of the streets' illumination requirements. Thus, lamps of 50 or 80 watts serve as minimum lighting on residential streets. A frequently applied size is the 125-watt lamp for streets with some traffic. Until recently, the 250-watt lamp was widely used for traffic streets and thoroughfares and even new heavily traveled auto routes. However, the 400-watt lamp with its 20,000-lumen output range now shows quite general application for important roadway lighting.

Plazas and squares with their converging traffic and pedestrian density, where pronounced high illumination levels are natural, are frequently lighted by single 1000-watt lamps per luminaire. This lamp size is preferred in most instances to the employment of multi-lamp arrangements of 250- or 400-watt lamps per luminaire.

Fluorescent

Fluorescent lighting is much in evidence and has been fulfilling a place as an illuminant in public lighting for quite a few years. It has appealed to lighting designer and public alike.

The lamp is chosen for various considerations, as

in this country. Color characteristics of fluorescent lamps have satisfied the amenities for illumination of pedestrian areas and public places. The low power consumption is a foremost factor in its choice. Over-all, the feature of modernity of the fluorescent lamp and its fixture when first introduced created a new interest in public way lighting, and this source has been and is now serving on various classes of streets and in particular areas.

Nevertheless, some limitations have evolved in fluorescent lamp experience to date, and fluorescent installations are not as much in demand as when this source was new, unique and the "mode" in street lighting.

One disadvantage is the inability to obtain large lumen outputs per luminaire without incorporating several lamps in the design. The provision for ballasts and wiring and the frequent lamp changing is an item contributing to steeper maintenance costs with this source, some authorities say.

The most widely used lamp sizes are the 30, 40, 65, and 85 watts. Very high output fluorescent lamps have not been applied for regular street lighting service.

Sodium

A third electric discharge type light source, the sodium lamp, has been lighting the streets of some European countries for years. For them this source has fulfilled two desirable points—economy in electricity consumption, and the low brightness properties of the lamp and its luminaire. Its characteristic yellow color has precluded a more universal acceptance, dislike and objections by the public running from tolerant to violent.

Nevertheless, installations of this lamp have been accepted over the years and are a successful commonplace now in lighting public ways. In Holland, for instance, sodium is now being accepted by villagers on their residential streets, while only a short time ago the sodium lighting on through motor-ways was terminated at the village gateway.

Progress in this light source may be appreciated in noting the wattage sizes available. Lamps of 45 and 60 watts have served as minimum lighting and 80- and 140-watt lamps, the latter of 10,000 lumens, are used on roadways with vehicular traffic of varying volume.

Currently, much interest is shown in the higher powered sodium lamps announced at the CIE Sessions in Brussels in 1959. These are now under development by street lighting technicians in England and on the Continent for field service.

The particular feature that is extending the interest in sodium is the high efficiency now obtained in the newly developed linear sodium types, a 200-watt lamp, at 100 lu/w, capable of furnishing 20,000 lumens in one tube. Laboratory models promise even higher efficiencies. A second aspect of sodium is the improved visibility of "better seeing" associated with the monochromatic sodium light, a property advanced through recent investigations abroad and under continuing research for qualitative factors. Installations of the 200-watt lamp have been made and are being promoted particularly for the lighting of highways where motorists do not object to the color, in fact, prefer it.

Xenon

Note should be taken of the xenon lamp installations, of which there are several on the Continent. A very distinctive illumination is obtained from this source. These lamps are practical for high-

Figure 6 (left). Wall mounting in England. This installation uses 140-watt sodium lamps, but mercury and fluorescent are also commonly used.

Figure 7 (right). Span mounted street lighting on a Marseilles street.

power lighting of large street and plaza areas. The largest to date in service is 75 kw, with 2¼ million-lumen output. It is mounted approximately 100 feet above the ground. The color approximates daylight and the illumination effect is extremely pleasing as well as spectacular.

Installation Practice and Methods

Many interesting equipment arrangements are followed in lighting installations in Europe. Lighting that is classic in many cities is the incandescent bowl fixture often suspended over the street by span wires anchored on building fronts. Medium wattage lamps prevail, 150 to 200 watts, but larger sizes including 750 watts continue in service.

The span wire method is, in fact, highly practical since in cities and congested areas the building facades are continuous along streets and also generally several stories high, insuring good mounting heights. It has been feasible to continue this construction in modernized jobs using mercury lamps. In so doing it is possible to obtain increased light output per fixture by the lamp size chosen and to reduce servicing trips by reason of the longer lamp life. Fluorescent luminaires are supported by the same span wire construction in many areas and this is a favored lighting arrangement in several countries.

The luminaires, of whatever kind, are mounted well above the street, at close spacing, 80 feet being typical. The symmetrical, or approximately so, light patterns overlap adjacent patterns, giving continuous light distribution along the street. Their position floods light downward on the building fronts and on sidewalks as well.

On streets lighted predominately for traffic, the span wire construction sometimes uses two luminaires per span, one directly over each vehicular traffic lane. Pole structures to support span wires are added where situations require them.

A frequent arrangement is the mounting of luminaires directly on building fronts, business or residence, or on brackets extending outward from the building over the street. An interesting point is that in some countries the government has the right by law to affix lighting to any building. This custom goes back a few centuries when certain householders were designated to provide some kind

of flame lighting at their doorway at night to mark the traveled way.

On the suburban class of residential street, low-wattage mercury or sodium lamps on pole systems have been selected quite widely in modernizing lighting over the past decade. Fluorescent as well has been chosen for relighting, and although the electric discharge lamps are taking over the job of roadway illumination at an accelerated rate, the familiar incandescent still lights the greatest total amount of road mileage.

However, change is the order, from the residential street need to the most exacting requirement for traffic thoroughfares and motor-way lighting. Under the pressure of the explosive increase in vehicular traffic, road building and civic developments, the trend is to larger light sources and their luminaire types, higher mounting, more efficient and effective light distribution.

Innovations in lighting systems are contributing to the attention given to more adequate public way lighting. Shadowless lighting for large street

Figure 8 (right). In Frankfurt, Germany, sixteen 40-watt or sixteen 20-watt fluorescent lamps in each mast are used to light this major traffic circle. The high lighting levels make this nighttime photograph seem almost like a daylight view.

Figure 9 (below left). Fluorescent street lighting pole in Paris is also used for mounting batteries of floodlighting projectors used to illuminate the beautiful building in the background.

Figure 10 (below right). Residential street lighting in Eindhoven, Netherlands, uses 32-watt circular fluorescent units on low mountings.

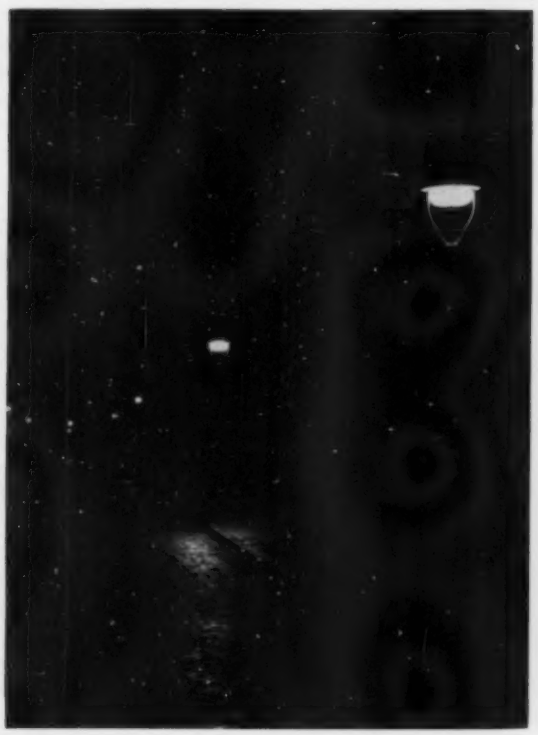

Figure 11. Notable European highway lighting includes mercury installation on Autoroute du Sud in France.

areas having dense vehicular and pedestrian traffic is realized by multiple luminaires per pole, such as four or five fluorescent units or four or six 2-lamp mercury units clustered at heights of 40 feet or more. An imaginative mounting innovation, in striving for quality of light distribution, is the longitudinal positioning of fluorescent fixtures on catenary suspension over the center of the streets.

An extension of the post-top idea has produced rather bold results as to size and lamp capacities accommodated. These newer designs are of a size, for instance, to enclose three 400-watt mercury lamps wtih a 50,000- to 60,000-lumen total output and are mounted at around 30 feet. Though somewhat unconventional, they are suitable at good heights for lighting promenades, open areas, parkways and, as reported in a recent case, for heavily traveled streets in a city.

An application that has been termed "high power lighting" is attracting interest and proving popular. The system mounts groups of large capacity lamps or a single lamp type of comparatively enormous lumen output on unusually tall poles or masts for high footcandle illumination over large areas. The field of high-power lighting for typical levels of 10 to 30 footcandles is growing. There are economic possibilities in that this method eliminates the otherwise numerous poles and moderate sized light sources needed to furnish the desired footcandle level and cover the lighted area. This high-mounting departure produces spectacular lighting not only for squares and public places but is likewise intriguing for lighting complex roadway facilities of a highway system. In this application, the entire facilitary area, that is, the overpass, lanes and grass plots, all are visible under the flood-lighted result. The effect to the vehicle driver may be imagined since he sees the area in broad view—the lanes, curbs, structures, signs and car movements—much as in daylight.

Luminaires

In reference to luminaires, or "fittings," "fixtures," and "lanterns" as customarily termed abroad, some brief detail will point up certain design ideas and developments in this equipment. Such equipment consists of many shapes and sizes, ideas and concepts, whims and creations, aside from the simple, deep bowl and open reflector already mentioned. The odd design point in relation to U. S. types generally is the wide use of open bottom styles. These mount one- and frequently two-bulb type lamps per fixture. Even some large sizes, the 400-watt mercury and the 140- and 200-watt sodium employ these open bottom fixtures.

Open styles, obviously, require frequent cleaning of the unit, otherwise poor maintenance and inefficient operation must be tolerated. Many installations would not meet the maintenance standards in the U. S., although the illumination product might be highly satisfactory from a visibility standpoint.

Recently, however, lighting authorities have turned to more luminaires of the enclosed design and the equipment suppliers now offer these for all light source types. Mechanically the equipment is superior to the former product, more dirt free and easier to maintain. Fluorescent units have profited by design improvements as they have been made, and are enclosed types by necessity.

Optically, the light distribution of a given luminaire for bulb type lamps may be diffuse, or controlled as to high, medium or low angle maximum beam. Both open and enclosed luminaires employ reflector optical control in deriving a particular design of light distribution. Polished aluminum reflectors are favored in much of the latest equipment. More efficient designs are the pressed glass refractor type for horizontal operation of mercury lamps; and, peculiar to Europe, moulded plastic fixtures for sodium lamps.

A modern style of luminaire is the long bay housing of approximately 30-inch length, mounting two mercury or sodium lamps in tandem, each lamp with its individual reflector. This design may be fitted with incandescent lamps as well.

Among the newest luminaires is the pleasing design of a basically slender housing and shallow plastic cover of 48-inch length over-all which accommodates two linear lamps, either fluorescent or the 200-watt sodium. Another design specifically for the 200-watt linear sodium lamp incorporates polished internal reflectors and moulded plastic

prisms on the cover for vertical angle light control. Other ideas are pylon types enclosing vertically positioned fluorescent tubes and fixtures designed specifically for building wall mounting to furnish street illumination.

The post-top fixture with its considerable variation of shapes and sizes has expanded to include designs having a canopy of 48 inches or more in diameter topping off the out-sized bowl which houses lamps of large rating.

Only limited reference can be made here to the great variety of luminaire types and their design features. Though traditional designs persist in places, there is a strong trend toward new designs, even innovations, for improved performance and with larger lamp ratings and lumen outputs.

Poles

Poles, or "lighting columns," are extensively used, as may be supposed, to support luminaires and are generally either tubular or concrete. Some aluminum columns are making their appearance. Wood line poles serve in many instances in outlying or rural areas.

Functional design and lack of adornment describe the present styles. Architecturally, the more recent column designs incorporate the features of slenderness of shaft, small base size and the integration of luminaire form and contours with those of the column. A noticeable fact is that though columns are closely spaced on important lighting installations, they are not unduly conspicuous or obtrusive as a pole system.

An observer readily notes the generally high mounting heights in most lighted areas, particularly on the Continent. A 30-foot height for the light source is common (for span wires as well). The trend is toward even higher mounting, and the newer traffic roadway installations are planned, in many cases, for 35 and even 40 feet. In England, 35-foot mounting has been used with the new 200-watt sodium lamp applications.

Tall poles and masts for high-power lamps and their equipment have now been added to modern lighting technology in several locations on the Continent. These mountings ranged from 50 to 70 feet for the first projects; recently 100-foot masts have been used for unusually high mounting cases. The installation problems are primarily those in the structural field.

While the special and unusual has its place and value, utilitarian poles, 15 to 35 feet in height, serve the various opposite, staggered and one-side lamp unit spacing arrangements for a wide range of streets. The double arm column set in the median strip of a divided roadway is a prevalent method of pole and luminaire installation.

Roadway Structures

Roadway structures such as bridges and viaducts, underpasses and tunnels, receive individual attention in their illumination treatment. With bridges and viaducts, low-mounted rail lighting is an alternative to the conventional pole installations which are often unacceptable architecturally. A continuous line of fluorescent fixtures is the most usual application and the fixtures are mounted on railings and parapets or sometimes ingeniously built in the railing construction. Such lighting is special for each case and authorities report that low-mounted projects invariably cost several times that of the pole and luminaire installation. Strict screening of radiating light, axially and transversely to the fixture above the rail, is essential in

Figure 12. New Rung Road in Birmingham, England, also uses mercury—in globular fixtures mounted at 30 feet.

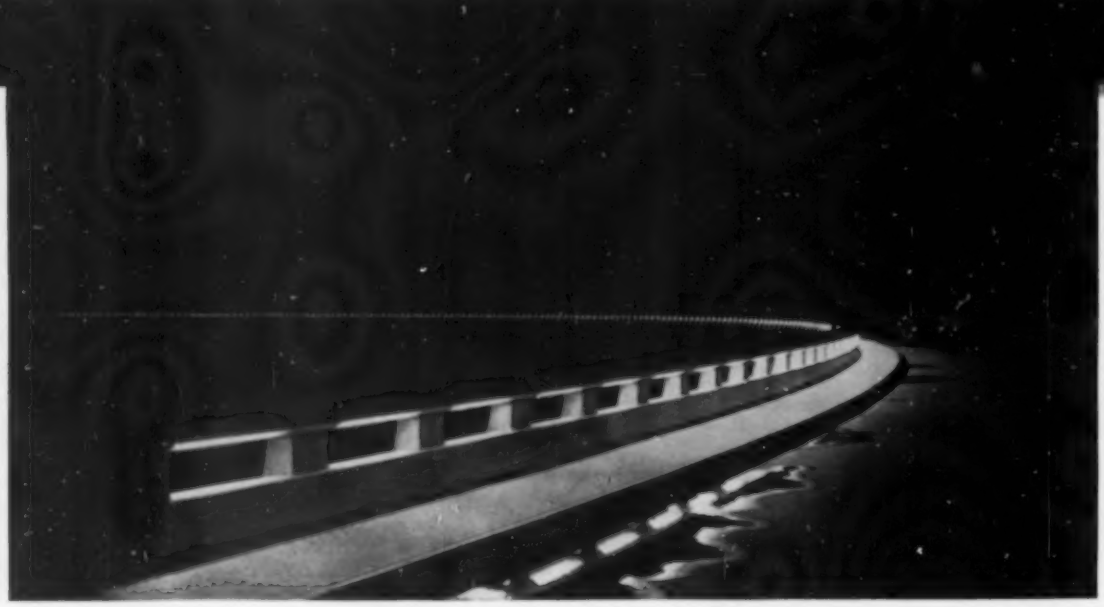

Figure 13. Fluorescent bridge lighting in Portugal.

protecting car drivers and pedestrians from objectionable glare.

Flush mounted fixtures for mercury, sodium and fluorescent lamps are used, in some cases, in parapet walls for lighting on the roadway. Such equipment performs mainly as beacon lighting.

Tunnels and long underpasses show various lighting solutions as to sources and fixtures or fittings. The usual application consists of continuous fluorescent rows, although one recent installation used closely spaced recessed fluorescent fixtures in the tunnel roof. Sodium lighting has been installed in some early tunnel and underpass projects. Supplementary lighting at the entrances to avoid abrupt changes between daylight and the tunnel lighting level is regarded as essential.

Illumination Characteristics

The quality of European roadway lighting may be appreciated by noting the concepts that govern the provision of (1) the lighting intensity level, (2) distribution on the roadway and, (3) the control of glare.

While all three are related in deriving a satisfactory end product, good visibility is probably equated by most observers with lighting which has good glare control. In this connection it should be explained that it is the custom in Europe to drive without car headlights, using parking lights only, where street lighting provides sufficient visibility for the vehicle driver to operate safely. The control of glare from the fixed lighting affords improved visibility to the driver; this objective is furthered by the absence of headlighting.

Much emphasis is placed on keeping glare within acceptable limits and this is accomplished by sharp shielding properties in the luminaire design (though high mounting may be a part of the final effect). It is probably the most distinguishing feature of European lighting practice, and is termed "cutoff" lighting to describe the restriction of light radiating at the high angles of the luminaire. Thus, to illustrate, the luminaire optical design provides a maximum luminous intensity at 50 to 60 degrees from the vertical and with very small intensities at angles above 80 degrees. Cut-

Figure 14. Tunnel lighting in Paris. Wall niches on close spacing each contain one fluorescent and two sodium lamps. Unique car-level standards between pillars use two, four or six lamps, graduating from the middle to the ends of the tunnel. Higher levels, of course, are toward the daylight ends.

off lighting is attracting more attention and interest in achieving quality illumination and is, in fact, being forced on the designer by the trend to high lumen lighting in which strict glare control is more demanding.

It has been reported that the CIE test road in Brussels will continue as a study project of the cutoff lighting principle with various luminaires and fittings, light sources and mounting heights. The results are expected to make an important contribution to the evaluation of effective roadway illumination.

Quantity

As for lighting intensity levels, there has been a steady rise in the footcandle levels (which is continuing) for the various classes of streets, to meet visibility demands associated with higher car speeds, congestion of cars and other purposes. For important traffic streets, levels of 1 to 1.5 footcandles are quite usual and values of 2 to 3 footcandles are frequent on "ring" roads and boulevards which are heavy volume traveled ways. Urban streets, such as in shopping districts and the prominent business and commercial areas, show levels of 4 to 5 footcandles for dense vehicular and pedestrian traffic and a general atmosphere of well being. The creation of bright spots and spectacular lighting treatments of squares and plazas frequently mean levels ranging from 10 to 30 footcandles. Secondary and residential streets without important traffic have varying levels under 1 footcandle.

Quality

The third element bearing on the quality of lighting is the luminance (brightness) and the nature of the pattern on the roadway for creating good conditions for observing and identifying objects and physical features along the roadway. The importance of luminance has led to research and investigations in recent years, particularly in The Netherlands and England, on the range of luminous levels required for safe and comfortable driving on various classes of streets and roadways.

Further investigation to derive quantitative figures is underway. However, sufficient experimental data have been developed so that the comprehensive new Netherlands' code of lighting practice, issued in 1959, now bases its recommendations on luminance (footlamberts) rather than illumination (footcandles).

Values are specified in the code for luminance and the uniformity of the pattern for the several classifications of roadways studied, both urban and rural. These values range from 0.6 footlambert and a uniformity ratio of 3:1 for motorways with dense, fast traffic to 0.15 footlambert and a ratio of 10:1 for residential streets without important traffic.

The uniformity ratio, one of various items pertaining to the provision of luminance and the pattern, is an important consideration, as disclosed by investigations of lighting abroad. A low ratio of luminance across the road, as well as laterally, affords a broad, full view of the roadway ahead. The vehicle driver is able to observe not only the pavement and the objects on it, but critical areas such as curbs, walks and grass verges, as well as riders on bicycle paths on the side of the road.

A notable high-lumen lighting project more proficient than any in service is proposed for the new Rotterdam-Hague four-lane, divided, high-speed motorway. This installation will utilize the 200-watt linear sodium lamp at a mounting height of 40 feet. The lighting level will be 3 footcandles maintained and speeds will be unlimited.

This important development in lighting will be of intense interest to lighting authorities in evaluating high level illumination for dense, high speed traffic. The experience data on several aspects of lighting and traffic will be extremely valuable.

Conclusion

There are several impressions gained in a review, though necessarily brief, of roadway lighting in Europe. In equipment, light sources have variety, are improving in efficiency and are available in larger lumen outputs. Luminaires are multiplying in number and offer a wide choice to the user; they incorporate more suitable optical systems and show concern for appearance and esthetics in their design. Poles and columns are functional and appropriate in appearance for their places. Lessons on maintenance are being learned.

More is being learned constantly on how to apply lighting effectively and innovations are not held back. Quality of lighting is being stressed more and more and the administrative and financial aspects play increasingly important parts. The status of public way lighting moves with the growth and fortunes of municipalities and governments. Timely research and upgrading of technology points to more adequate light on streets already lighted and to intensified lighting on new motorways.

Acknowledgment

The author thanks Philips' Lighting Service Bureau, Eindhoven, Netherlands, for Figs. 1, 2, 3, 5, 10 and 13; J. M. Waldram, Research Laboratories, General Electric Co., Ltd., Wembley, England, for Figs. 6 and 12; Ludovic Gaymard, Electricité de France, Paris, for Figs. 7, 9, 11 and 14; *International Lighting Review*, Amsterdam, for Fig. 8.

Factors Affecting the Efficiency of Street Lighting Systems

By JOSEPH C. YAEGER
HAROLD A. VAN DUSEN, JR.

"To promote safety and convenience for vehicular and pedestrian traffic through adequate visibility during darkness." With this cryptic phrase the major purpose of roadway lighting is described in the *IES Lighting Handbook*. Second only in importance to safety, adequate roadway lighting serves as a deterrent to crime, vandalism, and other acts of violence.

If a roadway lighting installation is to reduce accidents and crime effectively, adequate levels of illumination must be maintained throughout the life of all of the components of the system and under all the environmental conditions indigenous to the particular geographic location of the system. In this paper, the sole criteria for comparison of the effectiveness of lighting systems will be the incident footcandle level on the roadway. For purposes of simplification, all the other factors which contribute to visibility—glare, reflectivity, uniformity, etc., will be eliminated. To prevent any misunderstanding or misinterpretation of this discussion, it should be pointed out that it definitely is *not* intended to imply the superiority of any type of light source or lighting system. Rather, it is hoped that the compilation and discussion of all factors likely to reduce the output of lighting systems (which are well known but often overlooked) will inspire lamp and equipment manufacturers and system designers to take steps to improve the performance of future lighting systems.

The ideal or theoretically perfect roadway lighting system would utilize 100 per cent of the light output of the source to provide absolutely uniform levels on the roadway surface with no reduction of the levels due to line voltage fluctuations, dirt, weather changes, or manufacturing tolerances of the components, and maintain these levels throughout the life of the source. Obviously, the perfect is unattainable. However, the goal of all those concerned with roadway lighting should be to approach the perfect as closely and as economically as possible.

Incandescent Systems

It is somewhat ironic that the venerable series incandescent systems can approach perfection to a greater degree than systems employing modern, highly efficient light sources. This is due mainly to the fact that although the light output of an incandescent lamp tends to decrease as the lamp ages, due to bulb blackening caused by evaporation of the filament, the wattage of the lamp will be increased because the current is maintained at a constant value by the regulator. This increase in lamp wattage compensates for some of the reduction in light output due to blackening and tends to maintain the light output at a constant value. (See Fig. 1.) It is quite common practice to group replace 3000-hour life lamps at the end of 2000 hours, and under these conditions, the light output of the lamps on a series incandescent system will be

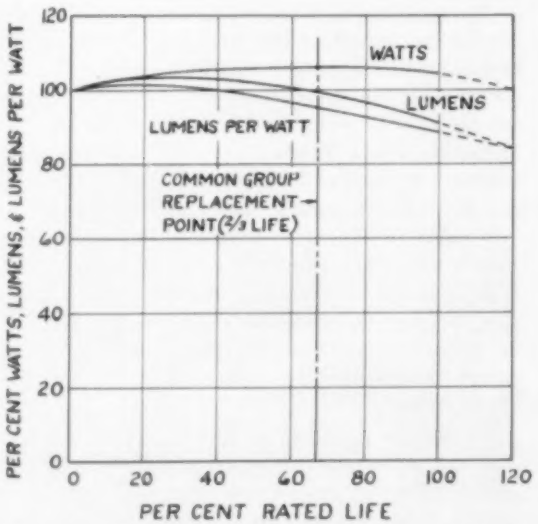

Figure 1. Representtaive operating characteristics vs. life of large series incandescent lamps.

A paper presented at the National Technical Conference of the Illuminating Engineering Society, September 11-16, 1960, Pittsburgh, Pa. AUTHORS: Line Material Industries, South Milwaukee, Wis. Accepted by the Papers Committee as a Transaction of IES.

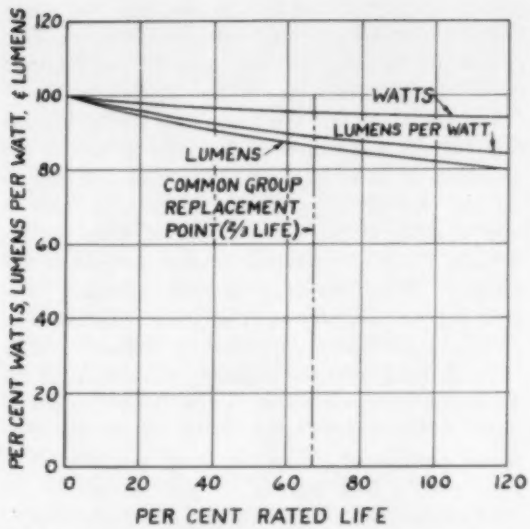

Figure 2. Representative operating characteristics vs. life of large multiple incandescent lamps.

essentially constant and at 100 per cent of nominal rated lumens.

For roadway lighting purposes, the small size of the incandescent source is an inherent advantage. Optical systems can be readily designed to provide good control of the light. Also, incandescent lamps have been around for a long time which means that luminaire design has become quite sophisticated and a relatively high proportion of the source output is utilized on the roadway. A well-planned incandescent system with typical luminaires can easily utilize 50 to 60 per cent of the source lumens on the roadway. Most series circuits are powered by moving-coil type regulators which have the ability to compensate for line voltage fluctuations of plus or minus five per cent. This is a definite advantage because the light output and life of incandescent lamps are greatly affected by variations in current and/or voltage. Assuming that the regulator is supplied by an average feeder, the life of the lamps on a series circuit should be very close to ratings supplied by lamp manufacturers, and light output should be uniform night after night and never fall significantly below 100 per cent of nominal.

About the only other factor that reduces the light output of luminaires on series circuits is that old bugaboo—dirt. Needless to say, accumulations of dust, soot, insects, and other foreign matter will reduce the amount of light emitted from any luminaire whether it is incandescent, mercury or fluorescent. For the purposes of this paper, we can assume that our hypothetical series circuit is located in an area where the atmosphere is relatively clean and free of industrial contaminants. In addition, if the luminaires are cleaned at least twice a year, it is possible to keep the losses due to dirt to about 10 per cent.

When they are new, 3000-hour-life series incandescent lamps have a luminous efficiency of approximately 18 lumens per watt. Typical series incandescent luminaires will provide slightly better than 8 lumens per watt on the roadway surface (see Fig. 8) when operated in accordance with the preceding discussion.

In spite of the many good features of series circuits, there are several disadvantages which have led to the widespread unpopularity of this type of circuit at the present time. One of the major disadvantages of series circuits is the high voltage present between the lighting loop and ground. The presence of this voltage makes it mandatory that large clearances must be maintained between the lighting conductors and other circuits that may be carried on the same poles. Maintaining this required clearance can be very costly because of the large numbers of circuits on most poles in our cities today.

Maintenance is another big problem on series circuits. Servicing crews have to be especially trained to work on the high-voltage circuits. Due to the high cost of labor, film cutout replacement can become expensive. Lightning is also a threat because there is no really effective means for impulse protection of series circuits. One way of eliminating the problems encountered on series incandescent circuits is to install a multiple system, perhaps with individual photoelectric controls for each unit.

From an installation and maintenance standpoint, the multiple system may offer some advantages. However, insofar as the efficiency of putting lumens on the roadway is concerned, the multiple incandescent system is inferior to the series circuit. Two new factors now arise which tend to reduce the amount of light on the roadway. First, the light output of multiple incandescent lamps does drop off with age. If 3000-hour-life multiple incandescent lamps are group replaced at 2000 hours (two-thirds life), the lumen output can be expected to drop to about 86 per cent of initial, as illustrated in Fig. 2. Furthermore, as shown in Fig. 7, the light output of multiple incandescent lamps can be reduced by circuit voltage drops and line voltage variations. A five per cent drop in applied voltage will cause the light output of an incandescent lamp to drop off to 82 per cent of the value supplied at rated voltage. Operating over-voltage is not good practice because a five per cent increase in voltage can reduce life to 55 per cent of rated. At the time of installation, 3000-hour-life multiple incandescent lamps generally have a luminous efficiency of slightly over 16 lumens per watt. Two thousand

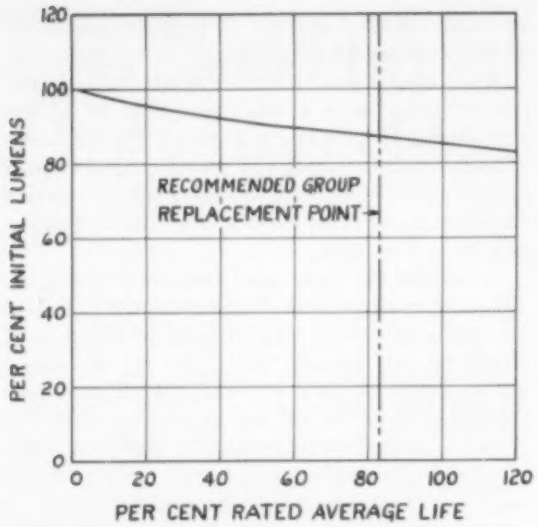

Figure 3. Typical lumen maintenance for the H-33 type mercury lamps.

hours later, when the lamps are ready for replacement, the luminous efficiency of the light falling on the roadway surface could be something less than 6 lumens per watt due to reductions of light output caused by: (1) reduction in light output of lamp due to aging, 14 per cent; (2) lumen loss due to five per cent drop in applied voltage, 18 per cent; (3) light not utilized on the roadway, 47 per cent; (4) losses due to dirt accumulation, 10 per cent.

Mercury Systems

Mercury lamps have a very high luminous efficiency, compared to incandescent. Including losses in the ballast, a mercury lamp can produce about two and a half times as many lumens per watt as an incandescent lamp. The useful life of mercury lamps is several times as long as that of the incandescent lamps used in street lighting applications. In general, burnouts are not a problem with mercury lamps since most of them will operate far beyond their rated lives. However, the light output of mercury lamps does decrease with age and if lamps are left in service too long, operation will become uneconomical. A good rule of thumb for the use of the latest types of mercury lamps (H-33) is to replace them somewhere between three-quarters and five-sixths of rated life, that is, around 9000 to 10,000 hours after installation. Fig. 3 illustrates the drop off in light for a typical mercury lamp of the H-33 type.

The type of ballast used with a mercury lamp has considerable effects on the operating characteristics of the lamp. Many papers have already been written about the pros and cons of the several types of ballasts available for mercury lamps. To prevent any misunderstanding and to preclude the possibility of reviving any hassles over the subtler points of mercury ballasts, only the more obvious features of two types of ballasts will be considered.

The simplicity and low equipment cost of reactor type ballasts make them particularly attractive for operation of H-33 type lamps. In addition, due to the fact that H-33 type lamps can reliably start in cold weather at 240 volts, operation with reactor ballasts is entirely feasible in most sections of the country. When installed on well regulated lines used only for roadway lighting, reactor ballasts can provide satisfactory operation of mercury lamps.

To conform with the sequence established in the discussion of incandescent lamps, the reduction of light output due to lamp aging will be the first factor considered. Mercury lamp manufacturers have come a long way in the past decade in the improvement of this characteristic. Nevertheless, at the recommended replacement point, the light output of H-33 lamps drops off to approximately 87 per cent of initial. Since the minimum amount of light on the street is the determining factor for our calculation of efficiency, this 13 per cent reduction is significant.

The lumen output rating of mercury lamps is based upon photometric measurements taken with the lamp operated on a Standard Reactor. A Standard Reactor may be defined as a variable inductor, relatively large in size, operated at relatively low flux densities in order to have precise characteristics. It produces lamp current waveshapes that are very nearly sinusoidal. Commercially available reactors and ballasts cannot be produced economically with electrical characteristics which exactly match those of a standard reactor. Therefore, the light output of a mercury lamp is usually lower when it is operated on a commercial reactor or ballast than when the lamp is powered by a standard reactor. The light output of a lamp operated by a commercial ballast or reactor divided by the light output of the same lamp operated on a standard reactor is expressed as a percentage and commonly referred to as "Per Cent SRL." A well designed reactor will usually have a Per Cent SRL of about 95 per cent. Hence, we have lost another five per cent of the rated lumen output of the lamp.

Reactors are operated on multiple circuits which means allowances must be made for line drops and line voltage fluctuations. On a well planned system, the total voltage drop can be held to about five per cent. As shown in Fig. 7, a five per cent in reduction in input voltage to a reactor ballast will cause an approximate nine per cent reduction in light output. Since minimum light on the roadway is our criteria, this is one more factor that subtracts

from the efficiency of roadway lighting systems. Most large mercury lamps (400 watts and higher) are operated in the horizontal position in roadway lighting equipment. Unfortunately, the lumen output of the lamps is determined from measurements taken with the lamps operating vertically.

The word "unfortunately" was used in the preceding sentence because the output of lamps operated horizontally is something less than when they are burned vertically. In fact, considerable variations in lamp wattage and light output have been measured when horizontally burning mercury lamps were rotated about their axes. In the absence of any reliable statistical data we will assume, for the purposes of this paper, that the reduction in light output due to operating the lamps in the horizontal position amounts to five per cent.

Relatively speaking, mercury lamps are small light sources. This permits optical systems to be designed with high utilization coefficients. A typical value of utilization for a well-planned mercury system, incorporating luminaires of reliable design, would be around 60 per cent. The only remaining factor to detract from light output is dirt. Here again, we can assume that a well maintained system will suffer about 10 per cent depreciation in light output due to accumulations of dirt within the luminaire.

In summary, when reactor ballasts are used with mercury lamps there are the following light output reducing factors: (1) lumen depreciation of the source, 13 per cent; (2) loss due to Per Cent SRL, five per cent; (3) losses due to line drop and voltage variations, nine per cent; (4) reduction in light output due to horizontal position of lamp, five per cent; (5) light not utilized on the roadway, 40 per cent; (6) losses due to dirt, 10 per cent. Referring to Fig. 8, the theoretical initial efficiency for producing lumens with a reactor ballast and an H-33 type lamp runs slightly above 48 lumens per watt. Under the minimum conditions explained in the preceding paragraphs, the light utilized on the roadway can drop to something around 18 lumens per watt. A mercury lamp on a reactor ballast could produce roughly 30 lumens per watt more than a series incandescent lamp. However, when the minimum lumens per watt utilized on the street are considered, the mercury system with reactor ballasts produces only 10 lumens per watt more than the series incandescent.

Perhaps a better method of comparison would be to define a "figure of merit" and compare systems on this basis. A "figure of merit" could be obtained by dividing minimum lumens per watt utilized on the street by a quantity we could call "initial efficiency." Initial efficiency is equal to the rated lumen output of the source divided by the input watts to the luminaire. The initial efficiency of a series incandescent system is roughly 18 lumens per watt. Dividing "minimum utilized lumens" by "initial lumens" we get a figure of merit for this type of system of .445. On the same basis a mercury system with reactor ballasts has a figure of merit of .38. A multiple incandescent system has a figure of merit of .355.

Regulating type or "constant wattage" mercury ballasts offer many advantages over most other methods of ballasting mercury lamps and are widely accepted for roadway lighting at the present time. In many instances regulating ballasts are the only type available that will operate mercury lamps satisfactorily under some conditions likely to be encountered in service. The operating characteristics that will be considered in this discussion do not clearly illustrate all of the advantages of regulating type ballasts—one more reason why we wish to emphasize that the comparisons of the various lighting systems in this paper are not to be construed as indicative of the entire means for judging the relative merits of the various systems.

Most of the factors that apply to reactor ballasted systems also apply to the constant wattage type mercury ballasts. The three exceptions are: "initial efficiency," Per Cent SRL, and the effect of line voltage drop and line voltage variations. The "initial efficiency" of a mercury lamp operated by a regulating ballast is slightly lower than that obtained from a mercury lamp operated by a reactor, due to higher losses within the regulating type ballast. Typical regulating ballasts have losses of from 50 to 60 watts yielding an "initial efficiency" of approximately 45 lumens per watt. The Per Cent SRL of regulating ballasts is lower than that of reactors due to the non-sinusoidal lamp current waveshapes inherent in all ballasts of this type. Regulating ballasts produced by reputable manufacturers have a Per Cent SRL on the order of 90 per cent.

As the name implies, regulating ballasts compensate for variations in input voltage. For this reason, an input voltage variation of plus or minus five per cent will normally cause no more than a one per cent change in lamp wattage and light output.

Percentages of reduction in light output due to lumen depreciation of the source, horizontal position of the lamp, utilization of the fixture, and losses due to dirt are assumed to be identical to those figures used for reactor ballasted mercury luminaires. As shown in Fig. 8, under minimum conditions, the light utilized on the roadway has an efficiency of slightly under 18 lumens per watt.

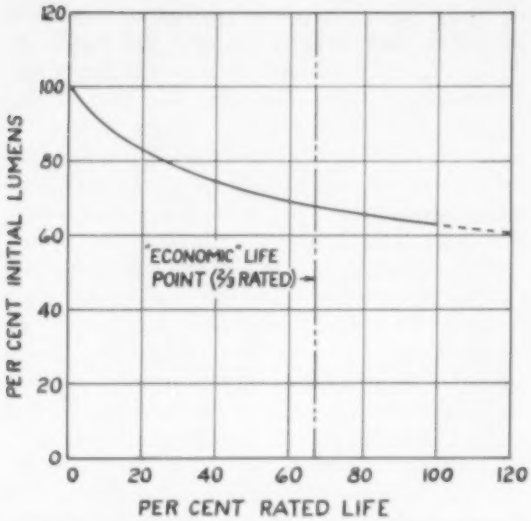

Figure 4. Representative lumen maintenance of 25-watt-per-foot fluorescent lamps.

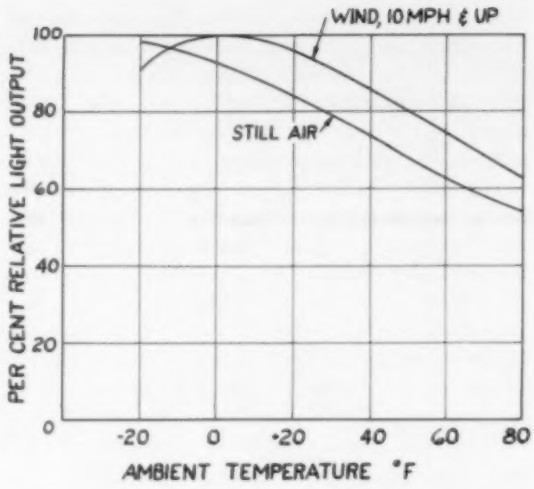

Figure 5. Effects of ambient temperature and wind on light output of a four-lamp fluorescent luminaire using 25-watt-per-foot lamps.

The "figure of merit," as defined previously, is .395 for a mercury system operated with regulating type ballasts.

Fluorescent Systems

Fluorescent lamps, like mercury lamps, are arc-discharge devices that employ mercury vapor as the gaseous conducting medium. Therefore, many of the factors that reduce the light utilized on the pavement are common to both systems. However, differences in operating pressure within the two types of lamps and the manner in which visible light is produced causes the fluorescent lamps to have a characteristic not shared by mercury lamps.

Two fluorescent systems will be compared. Both employ luminaires that contain four lamps operating with arc currents of approximately 1.5 amperes and are, therefore, loaded to about 25 watts per foot of nominal length. Ballasts are identical in both systems and are of the "series lead" type. Series lead fluorescent ballasts are very similar to regulating type mercury ballasts and do compensate for variations in input voltage, although not to as high a degree as do regulating mercury ballasts. The luminaires are assumed to be mounted perpendicular to the street. The only difference between the two fluorescent systems is that on one circuit the luminaires will be equipped with "controlled spot cooling." The light output of such luminaires is nearly independent of ambient temperature and wind.

Fluorescent lamps are characterized by a high luminous efficiency. In this respect they are even superior to mercury lamps. The "initial efficiency" (rated lamp lumens divided by input watts to the luminaire) of 25-watt-per-foot fluorescent lamps is on the order of 62 lumens per watt. Fluorescent lamps of this type also have relatively long life, but are somewhat inferior in this respect to mercury lamps. The present recommended economic life of 25-watt-per-foot fluorescent lamps is roughly half that of H-33 type mercury lamps.

The characteristic of fluorescent lamps not shared by mercury lamps is their extreme temperature sensitivity. Light output of fluorescent lamps varies widely with changes in ambient temperature. Because air movements affect the ambient temperature within a luminaire, wind, as well as ambient temperature, affects the light output of most fluorescent luminaires. The effect of ambient temperature and wind on a typical street lighting fluorescent luminaire is shown in Fig. 5. The temperature at which peak light output occurs and the shape of the curve are dependent upon the luminaire thermal characteristics, lamp type, and ballast characteristics.

The first fluorescent system to be discussed will be the one without "controlled spot cooling." Referring to Fig. 5, approximately 46 per cent reduction in light output can occur on a warm night. Under these conditions the input wattage to the luminaire will also be reduced to a lesser extent. The net effect is an approximate 30 per cent reduction in lumens per watt due to ambient conditions.

Lumen ratings of fluorescent lamps are based on lamps operated horizontally. Therefore, it is not necessary to apply any factors for lamp position. The lumen depreciation of 25-watt-per-foot fluorescents amounts to about 33 per cent at the rated economic life of the lamp (see Fig. 4).

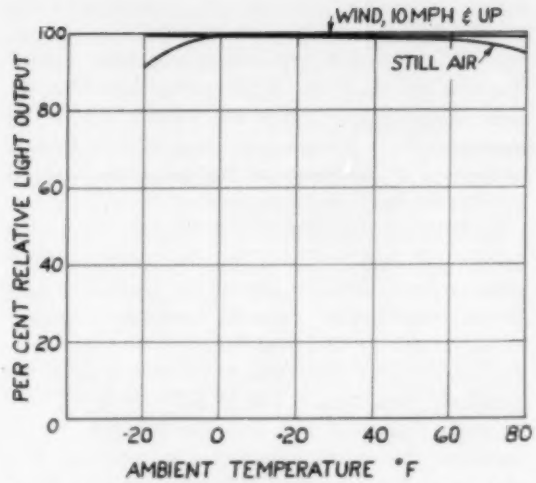

Figure 6. Effects of ambient temperature and wind on light output of a four-lamp fluorescent luminaire using controlled spot cooling.

A 10 per cent reduction of light output is typical for series lead ballasts due to the Per Cent SRL factor. The ballasts do regulate fairly well and for this reason only about three per cent of the light is lost due to a five per cent drop in applied voltage.

Since fluorescent lamps are large, linear light sources, good optical control is difficult. Considering only the light on the roadway surface the coefficient of utilization for a typical fluorescent luminaire would be around 36 per cent. In other words, a 64 per cent reduction factor should be applied. Once again we will assume a 10 per cent reduction due to dirt. The net effect, as shown in Fig. 8, is that under minimum conditions, the light utilized on the pavement, divided by the input watts to the luminaire, drops to a figure of 8.1 lumens per watt. The figure of merit for a system of this type is .131.

"Controlled spot cooled" fluorescent luminaires available at the present time contain devices that are capable of maintaining a very small portion of the bulb wall surface of the lamps at the temperature required for maximum light output from the lamps. It is a characteristic of fluorescent lamps that if a small spot on the lamp surface is maintained at this optimum temperature, the light output of the entire lamp will be maintained nearly at maximum. Fig. 6 illustrates how the effects of ambient temperature and wind are minimized by the use of "controlled spot cooling." A fluorescent system equipped with luminaires of this type would be subject to a reduction in light output of only about eight per cent due to ambient conditions through the range of —20F with wind to 80F still air.

All the other factors contributing to reduction in lumens per watt utilized under minimum conditions for fluorescent luminaires equipped with

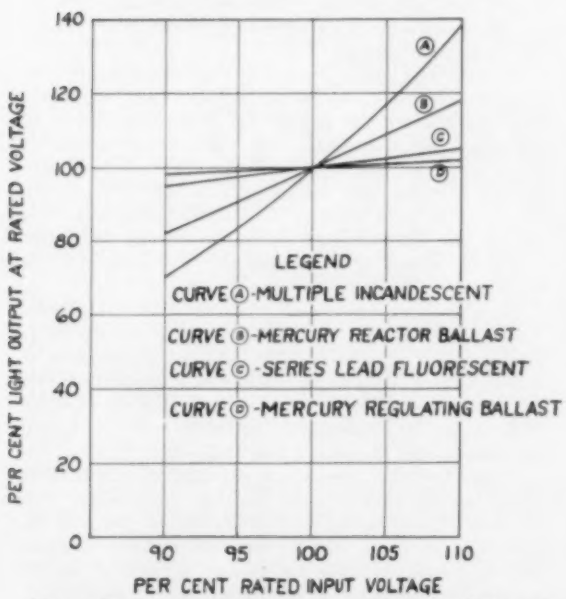

Figure 7. Effect of line voltage variations on light output of several types of lighting systems.

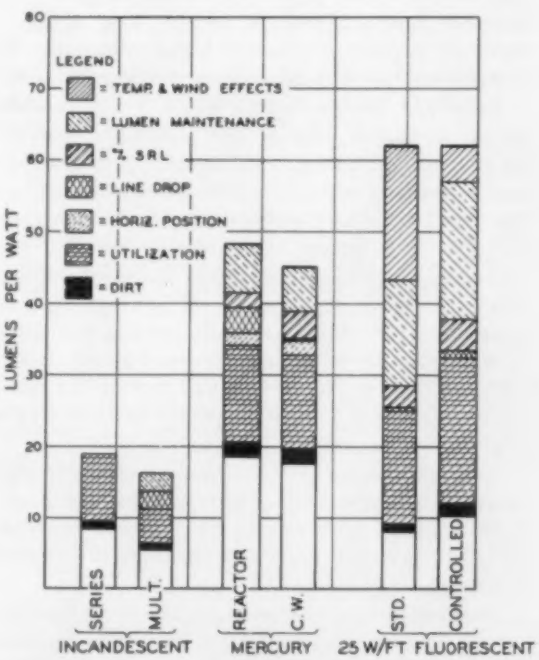

Figure 8. Comparison of efficiencies of street lighting systems. Unshaded areas represent lumens used on street at end of economic source life divided by input watts into luminaire. Values represent typical luminaires and will vary somewhat for various designs.

controlled spot cooling are identical to those listed for luminaires without this feature. When all these factors are applied, as shown in Fig. 8, the minimum efficiency of placing lumens on the roadway amounts to slightly less than 11 lumens per watt. The "figure of merit" for a lighting system of this type is .189.

Comparison of the lumens utilized on the roadway per watt input to the luminaire of the two fluorescent systems indicates that luminaires with controlled spot cooling are about 35 per cent more efficient than those without this feature. If lumen output per luminaire rather than lumens per watt is considered, the luminaires with controlled spot cooling are about 50 per cent more efficient. (This point was mentioned to illustrate the fallacy of using the efficiency figures quoted in this paper as a basis for judging the over-all merit of one system against another. The "figure of merit" defined in this paper and the relative efficiency data presented are only intended to show that improvements in equipment design and circuit planning are needed if the full potentials of the high efficiency light sources are to be used to maximum advantage.)

Conclusions

The theoretical gains possible by the use of high luminous efficiency gaseous discharge light sources are not fully realized in present day roadway lighting practice. A review of Fig. 8 reveals several areas where there is much room for improvement.

Improved optical designs which would provide better utilization offer a very significant increase in efficiency, although in this respect, a comparison of the roadway utilization efficiencies of the different types of lighting systems should not be the sole criteria for judgment of the relative merit of the systems. Fluorescent luminaires, in general, utilize almost as much light on the off roadway side as they do on the roadway side. In many applications this is a distinct advantage because the large quantities of light on the off roadway side of the luminaire can be used to light sidewalks, building fronts and surrounding areas.

Loss of illumination due to dirt accumulations can become appreciable if any system is not properly maintained. Losses of this type can be minimized by a well-planned and intelligently executed maintenance program.

Much progress has been made by lamp manufacturers in reducing the lumen losses due to lamp depreciation, especially with mercury lamps. Fluorescent lamps still depreciate at a relatively rapid rate. There is much room for improvement here. The effects of ambient temperature on fluorescent luminaires are very significant. Methods have been devised to reduce light output losses due to this stigma. The controlled spot cooled fluorescent luminaire is a marked improvement in this respect. There is still room for improvement in ballast design. Lower losses within the ballasts and better Per Cent SRL factors can contribute to greater utilization of the potential lumens available from gaseous discharge light sources.

In spite of the factors that tend to reduce the amount of light utilized on the roadway when gaseous discharge light sources are used, their high lumen output and superior luminous efficiency permits them to offer significant gains over incandescent systems. However, much higher gains are definitely possible and will be fully realized when everyone concerned with roadway lighting becomes aware of the shortcomings in his particular area and takes vigorous steps towards improvement.

DISCUSSION

H. F. WALL:* I welcome the opportunity to discuss this type of paper because of the chance it affords for presentation of my opinions as a user of commercial street lighting equipment. Higher and higher pressure marketing and production techniques and competitive selling have generally resulted in products of lower quality and the so-called "bread and butter" lines which are no longer equal to specific tools for street lighting.

There have been many significant developments in mercury and fluorescent light sources—a kind of race to produce the biggest and brightest products. There has been very little effort directed toward reducing the size of these sources and, consequently, it becomes increasingly difficult for the manufacturers to produce a luminaire of reasonable size and efficiency.

We have had many arguments with manufacturers of luminaires, ballasts and lamps because, when assembled, their products did not produce the candlepower shown in guaranteed published data. The combination of ballasts which deliver reduced wattage, lamps which are invariably average or below, and luminaires with wide physical tolerances works in a direction detrimental to the user. The factory guaranteed data for luminaires are derived by prorating the output of all components to a level which is never achieved in actual practice.

About two years ago, we purchased several luminaires designed from basically excellent theoretical considerations for use on our expressways. The combined performance of ballast, lamp and luminaire resulted in a candlepower output which was less than 60 per cent of what we expected. This seemed an unreasonable reduction from guaranteed performance and the project was finally abandoned.

I wish that the authors had extended their studies to street lighting systems using mercury lamps larger than 400 watts. In designing the lighting for our proposed expressways, we found that the currently available 400-watt mercury luminaires would not produce the desired level of maintained illumination in certain sections. It seemed logi-

*Public Lighting Commission, City of Detroit, Mich.

cal to substitute larger luminaires fitted with 700-watt mercury lamps, but we were amazed to learn that this increase in wattage raised the illumination level only 15 per cent using luminaires currently being manufactured. In view of these experiences, I believe that a detailed study might have revealed truly remarkable inefficiencies.

The latest research in street lighting by Dr. Blackwell indicates that an average of two footcandles is a reasonable level, yet I do not know of a single luminaire on the market today which will provide this level without unreasonably close spacings.

In addition to the figure of merit suggested by the authors, I recommend that all purchasers' specifications require a test on one unit of every 150 luminaires furnished, using a ballast and lamp chosen at random from the user's stock. These tests will be truly representative of how the equipment being furnished compares with original guarantees. It will also provide the user with a basis for urging the manufacturers to produce better equipment and indicate to the manufacturer wherein his products are deficient.

D. A. TOENJES:* The authors have reviewed the various light sources commonly used for roadway lighting in order to compare them on the basis of ability to deliver light to the roadway with present lighting systems. Such a review is welcome because its comparison of the various lamps is broad. Often studies are so concerned with the performance details of a particular lamp type or luminaire design that they fail to evaluate it with relation to the other available street lighting lamps and equipment.

Since the paper mentions various light sources and methods of operation, it might well have included a list of earlier references. Then, any reader interested in the details of one particular lamp or type of operation could be directed in his search through earlier literature.

In the introduction, the authors point out that they have simplified their criterion of judgment by comparing the various street lighting systems only in terms of illumination on the roadway. However, other factors which may properly be set aside for purposes of this comparison should not be discounted in their final effect upon visibility for the motorist. Obviously, a compromise must be worked out between utilization of light and visibility.

In Fig. 1, the authors show light output as continuing out to rated life and beyond in a smooth curve. For the series incandescent lamps, the filaments tend to weld when they would otherwise be broken toward the end of average lamp life. Such welds permit the lamps to continue burning, but at values of light output that have dropped downward abruptly. In a large typical group of lamps, the first filament welds may begin to occur at about 70 per cent of rated life or earlier. By the time of group replacement, some of the lamps will have two or three filament welds. Therefore, their average light output will have been reduced, and with more variation among individual lamps than is experienced with multiple lamps on well-regulated circuits. This would cause the right end of the average light output and wattage curves to droop, perhaps more than is shown in Fig. 1.

The section on incandescent systems describes the light output of lamps on a series system as being essentially constant at 100 per cent of nominal rated lumens. In our experience, the shape of this lumen maintenance characteristic depends upon lamp wattage. The smaller lamps show an increase in light output as a function of life, while the larger lamps have a drooping characteristic in which light output may drop below the initial value.

The authors also state that the life of lamps in a series circuit should be close to rated value. However, series lamps in actual street lighting operation are likely to have a service life that is considerably shorter than the average life under laboratory test conditions. On test racks there is no vibration due to traffic and wind conditions, nor the abnormally long inrush current which might result from sticking regulators or mixtures of different lamp wattages on the same series circuit. Such factors contribute to shortening lamp life in service, reducing laboratory life by about 10 per cent under average service conditions.

Lightning is mentioned as a threat to series lamp operation. Would the authors comment on its comparative effects on multiple circuits and circuits using mercury or fluorescent lamps?

In the section on mercury systems, the authors recommend replacement of mercury lamps toward the end of rated life on the basis of their decline in light output. This recommendation is reasonable for the 400-watt H-1 lamp and for similar lamps of that cathode design in other wattages. However, for the H-33 lamps with their improved lumen maintenance characteristics, it would be proper to ask whether lamp replacement at burnout might be more economical. Our cost of light calculations do verify the authors' recommendations of group replacement of the lamps at from three-quarters to five-sixths of their rated life. However, total cost of light with lamp replacement at burnout may be only slightly higher.

The paper describes mercury lamps as small light sources which permit optical systems to be designed with high utilization coefficients. This is even truer of clear mercury lamps. The phosphor-coated lamps, while often properly recommended for certain street lighting applications, do compare unfavorably in this respect because the arc stream of the clear lamp is a compact light source permitting much more precise optical control than does the luminous outer bulb of the phosphor-coated lamp design.

As indicated, light output varies as a function of lamp operating voltage. Choice of lamp ballast design has some effect upon the degree of this variation. For example, "constant-wattage" or "regulator" ballasts actually operate the lamps at close to a constant-current characteristic. Then, average light output is almost directly proportional to operating voltage. Such effects were described by Noel and Martt.[1] It should be noted that some of the constant-wattage ballast characteristics criticized in discussion of the Noel-Martt paper have subsequently been improved.

In the section on fluorescent systems, Figs. 5 and 6 show variations in light output as functions of ambient temperature and wind conditions surrounding a fluorescent luminaire. Rated light output of a lamp, measured with bare-lamp operation in still air at 77°F usually does not correspond to maximum light output. Since Fig. 5 shows the varying light output of lamps operated through a range of temperature conditions, it may be assumed to reach its peak at the approximate conditions of maximum light output from the lamps, although it is likely that all four lamps may not reach their peaks exactly together. Could the lamps represented in Fig. 6 have been artificially held at something other than maximum light output by the spot cooling devices? If so, then relative light output scales might not be the same for the two figures.

*General Electric Co., Cleveland, Ohio.

1. Noel, E. B. and Martt, E. C.: "Effect of Operating Variables on Mercury Lamp Performance," ILLUMINATING ENGINEERING, Vol. LI, No. 7, pp. 513-531 (July, 1956).

M. E. KECK:* The authors state that for purposes of this paper their "sole criterion for judging the effectiveness of a lighting system will be the incident footcandle level on the roadway." I am willing to accept this criteria for purposes of the paper. I trust that the later statement that "the theoretically perfect roadway lighting system would utilize 100 per cent of the light output of the source to provide an absolutely uniform lighting level on the roadway surface," is advanced as part of this criteria and should not be construed to apply other than for establishing the ground rules of the paper.

I feel that it is inconsistent of the authors to make the first limitation quoted above and then to devote a paragraph of the conclusion to the defense of the fluorescent luminaire on the basis of the "off the street light" which it provides. Such statement is not consistent with the sole criteria which the authors intended to use.

One rather large factor involved in determining the actual amount of light constantly available on the pavement surface has been neglected in the paper. This is the fact that some lamps *do* fail before group replacement time and the result is a very drastic reduction in the lighting level for the time that elapses before group replacement. If we assume that this time will be as short as ten operating hours, its effect on the relatively short life incandescent lamp will be considerably greater than its effect on the longer-lived mercury system. Also, such an effect would be considerably different on a fluorescent system which uses more than two lamps, since all of these might not be affected at the same time. Although his factor might be a somewhat more complex function than some of those included in the paper, I feel that it should be considered before determining the figure of merit.

For those who wish to pursue this subject further, a paper by Fraser, Unglert, Waldbauer and Walick[1] gives considerably more detailed information on the behavior of mercury lamps with various types of ballast circuits under varying voltage conditions and operating positions. Inclusion of this more recent data would probably have had a small effect on the figures of merit indicated in this paper.

1. Fraser, H. D., Unglert, M. C., Waldbauer, W. M. and Walick, J. A.: "How Operating Position and Circuit Variations Affect Mercury Lamp Characteristics," ILLUMINATING ENGINEERING, Vol. LVI, No. 3—Section II, pp. 215-221 (March, 1961).

J. C. YAEGER AND H. A. VAN DUSEN, JR.:* Mr. Wall's experience with 700-watt mercury lamps is probably not unique. Many early models of luminaires employing the larger mercury lamps had relatively poor optical systems. In order to expedite production of luminaires to accommodate the larger mercury lamps some manufacturers made revisions of luminaires that were originally designed for 400-watt lamps. Units of this type were inherently too small to provide satisfactory light distribution with the larger sources. This lack of adequate control made it impossible to raise the lighting levels in proportion to the increase in lamp wattage.

Mr. Toenjes' comments were enlightening and in some respects rather frank for a representative of a large lamp manufacturer. The lack of a bibliography was purely an oversight for which we apologize.

We concur with Mr. Toenjes' frank discussion of the well-known but seldom admitted life and lumen output characteristics of incandescent lamps.

We wish to point out that we are by no means experts in the field of impulse protection for lighting systems. It is unfortunate that very little information is available on this topic. From our own limited experience, we have noticed that it is extremely difficult to provide reliable impulse protection for series circuits. In addition, a surge on a series loop can result in failure of a large number of lamps and other equipment. On multiple circuits, a surge failure is usually confined to an individual luminaire. Multiple circuits with mercury and fluorescent lamp-ballast combinations can usually be protected by the use of secondary type arresters coordinated with the basic insulation level of the ballast. We expect that the use of arresters within each luminaire will become more widespread. This practice has been accelerated by the development of internally ballasted luminaires and the trend toward higher distribution voltages.

In the luminaire design described by Fig. 5, all four lamps reached their peak lamp output at substantially the same temperature. In the luminaire described in Fig. 6, each lamp is artificially held at maximum light output. The relative output scales for the two luminaires are, therefore, essentially the same. This would not necessarily hold true in all luminaire designs, and if the lamps in an uncontrolled luminaire peak at different times, then the light output of the controlled cooled version of that luminaire will represent a larger quantity.

We feel that Mr. Keck misinterpreted our "defense" of fluorescent luminaires in the conclusion section. We cited means for advantageous use of "off roadway side" light in some applications merely as one example of why efficiency, by itself, *cannot* be used to determine how well a lighting system contributes to the ultimate goal of good visibility. The paper was written to point out that improvements in roadway lighting systems are needed for more efficient use of the lumens generated by presently available light sources. However, we can never forget that increasing the efficiency is only one step toward providing the more important object of roadway lighting, namely, good visibility.

As Mr. Keck pointed out, early lamp failures can reduce light levels until the defective lamps are replaced. Our primary reason for omitting this factor was a lack of any complete or statistically correct data on early lamp failure rates. We also assumed that on well maintained systems, early failures would be replaced soon after they occurred.

*Westinghouse Lighting Division, Cleveland, Ohio.
*Authors.

INSTALLATION AT LINCOLN AVENUE STORAGE GARAGE FOR CITY OF MILWAUKEE, 3921 WEST LINCOLN AVE., MILWAUKEE, WIS.

Lighting a Garage Lubrication Area

LIGHTING OBJECTIVE: To provide general and local lighting in the lubrication rack areas of a large garage.

GENERAL INFORMATION: The lubrication rack areas that are shown in the photograph above measure 18 feet in width by 30 feet in length, with a ceiling height of 18 feet 6 inches. This garage, which contains several similar rack areas, has the following colors and reflectances for the major surfaces: ceiling, grey (15 per cent reflectance); walls, green (35 per cent reflectance); and floor, concrete (20 per cent reflectance).

INSTALLATION: General illumination is provided by Holophane catalog No. 635 low bay, open-bottom, open-top, prismatic glass reflector units, each equipped with a 400-watt H1LB improved-color mercury lamp. Two of these units are mounted at the side of each rack area at truss height or at lubrication reel height, as is shown in Fig. 2. One unit is also mounted at truss height at the center of each end of the rack area.

Local lighting is provided by Holophane

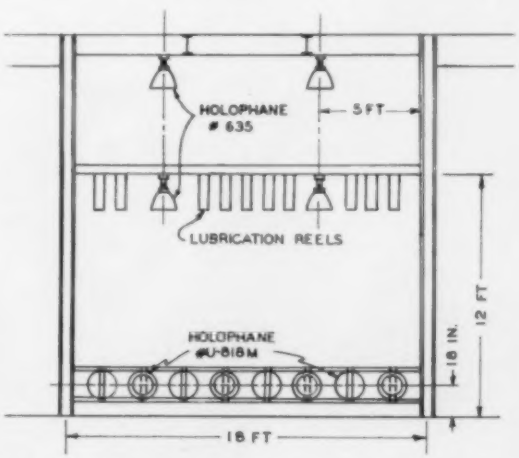

Figure 2. Section showing location of lighting units.

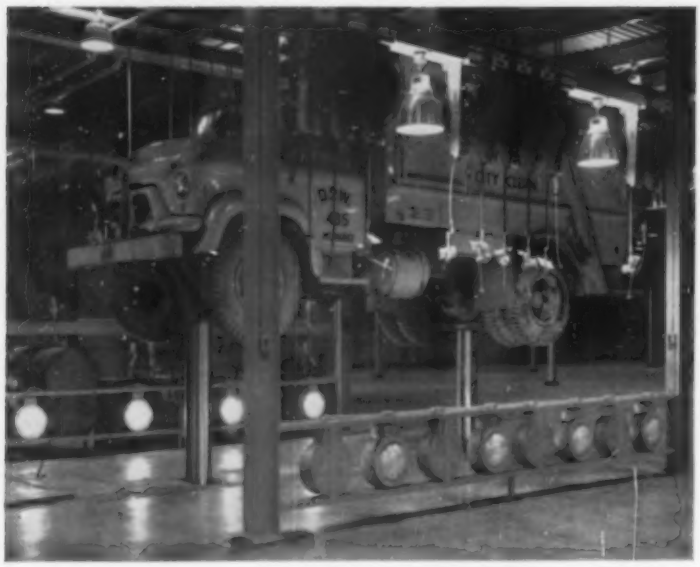

Figure 3. View showing truck in position for lubrication.

catalog No. U-818M prismatic glass lens units, each equipped with a 300-watt clear incandescent lamp. Eight of these units are mounted at the side of each rack area, as is illustrated in Fig. 2 (four facing into each lubrication area). The prismatic glass lenses are installed to direct the light upward.

Initial illumination readings from both the general and local lighting were:

floor at center of lubrication area	
without truck	100 fc
with truck (see Fig. 3)	70 fc
side of truck, 5 feet above the floor (vertical)	50-60 fc
underside of truck at drive shaft	30-40 fc

Lighting designed by Bureau of Bridges and Public Buildings, City Hall, Milwaukee, Wis. Superintendent, George Ashton; assistant superintendent, Larry Hager. Designing electrical engineer, Norb. Langkammer.

Lighting data submitted by Edward H. Grieb, District Manager, Holophane Co., and Jim Augustine, Lighting Consultant, Milwaukee, Wis., as an illustration of good lighting practice and to aid in the design of similar installations.

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Light Transmitting Plastic Enclosure For Outdoor Lighting Equipment

By DONALD E. HUSBY
MELVIN R. ANDERSON

A comparison is drawn between the relative impact strengths of street lighting enclosures made of glass and plastic in an effort to point out the parameters within which application should be made. Using present materials as a guide, a pattern of usage is being established to justify further refinement and development of plastics for outdoor lighting.

In the field of outdoor lighting, the major use of light transmitting plastic enclosures has been restricted to those luminaires which use a fluorescent lamp source. For simplicity, this type of enclosure shall be referred to as a clear plastic cover. Basically, these luminaires have been large, bulky, units, paying only the slightest lip service to appearance details, with one or two exceptions.

Generally, these units use a clear plastic enclosure, or globe, only for enclosing the lamp chamber from entry of insects, dirt, rain, or other contaminants. Only one known luminaire uses the clear plastic as a means of light control as well as a closure medium. This industry-wide choice of usage has been due mainly to the high cost attending the use of any other shape and the basic fact that if glass were used, the luminaire weight would be prohibitively great.

Until recently, there has been literally no use of clear plastic enclosures for luminaires other than those using fluorescent sources. Recently, however, there have been introduced two new clear plastic refractors designed specifically for mercury lamp source luminaires and one which is designed, in basic principle, for the incandescent source, although it is marketed for use with both incandescent and mercury sources and is not truly an enclosing refractor.

These new uses of the clear plastic are different from those used in fluorescent luminaires in that they provide the optical control which should be part of their function and are not just highly expensive covers which merely transmit light. These new clear plastic refractors indicate some basic dimensions inherent with each type and size of light source as compared to past practices using glass enclosures and mercury sources. Some of these dimensions are indicated in Table I. It is seen by this table that a particular type of luminaire source is de-rated in wattage or lumen rating when a clear plastic refractor is used instead of a glass refractor. This indicates one deficiency of present day materials insofar as outdoor, clear plastics, are concerned.

Considering a few of the application requirements of an enclosing media, factors such as vandalism, type of source, installation, maintenance practices and luminaire brightness must be considered to determine the worthiness of clear plastics as an enclosing member. Many claims made by other industries for plastics are tainting the promotion and acceptance of plastics in lighting applications. For an area plagued with high vandalism rates on glass refractors or globes, it is a

TABLE I.

PRESENT LUMINAIRE DESIGN	TYPE OF REFRACTOR MATERIAL	APPROXIMATE OPTICAL VOLUME (CU. IN.)	MAXIMUM WATTAGE RECOMMENDED
(B)	BOROSILICATE	600	250
(B)	METHYL METHACRYLATE	600	175
(C)	BOROSILICATE	1200	400
(C)	METHYL METHACRYLATE	1200	250
FUTURE LUMINAIRE DESIGN	TYPE OF REFRACTOR MATERIAL	APPROXIMATE OPTICAL VOLUME	MAXIMUM WATTAGE PROPOSED
(B)	"X"	600	250
(C)	"X"	1200	400

A paper presented at the National Technical Conference of the Illuminating Engineering Society, September 11-16, 1960, Pittsburgh, Pa. Authors: Lighting Division, Westinghouse Electric Corp., Cleveland, Ohio.

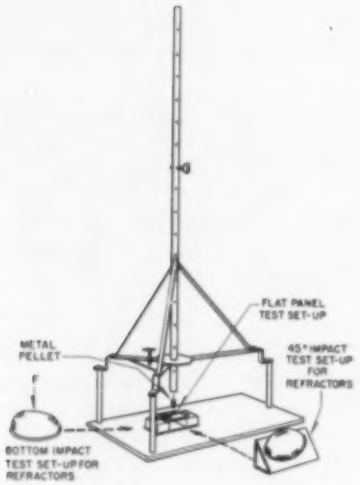

Figure 1. Impact test stand.

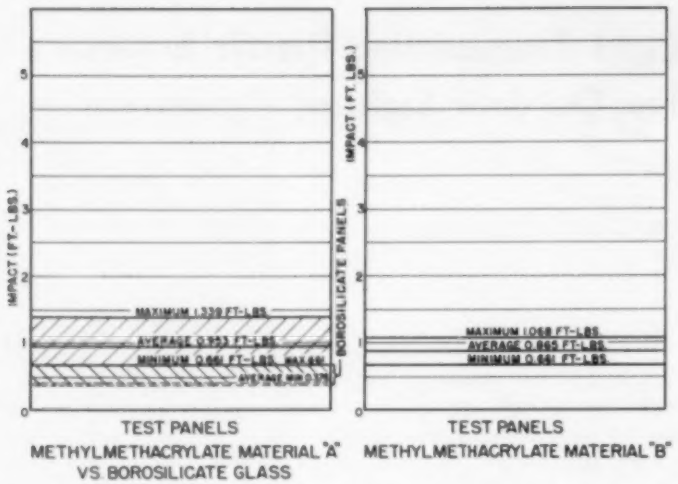

Figure 2. Comparison of resistance of glass and plastic media to impact.

natural tendency to either consciously or subconsciously wish, and oft times ask for plastic refractors, since plastic seemingly is unbreakable. In reality, however, plastics do break. True, some have higher resistances to breakage as compared to glass and some are nearly, for practical purposes, unbreakable; but are these materials applicable to the lighting field?

The purpose of this paper is not to delve into the chemistry of these plastics but rather to furnish data obtained from testing which most simulates the physical treatment these outdoor luminaire "enclosures" will receive in shipment, installation, and prolonged service. This testing consisted of inflicting blows on the test specimens at specific vulnerable surfaces and angles. Since a glass media is a past and present day enclosure with which users are very familiar, our tests used glass specimens as a control medium to relate the data obtained on the plastic specimens.

Test Procedure and Apparatus

Fig. 1 shows the impact test stand which was adapted to this test procedure. It consists essentially of a ten foot length of pipe through which a known weight may be dropped upon a test specimen at various known heights. The variable test positions used are indicated by side views of this diagram; that of flat panel specimens, refractor shapes which are subjected to impact at a 45-degree angle. One factor not considered in the determination of impact strengths was that of internal friction between the weighted pellet and the inside of the pipe as it drops through the test distance. Since all tests were performed on the same basis, this factor is considered negligible, since we are endeavoring to show here the relative values between glass and plastic.

The flat panels tested were approximately 4 by 6 inches and were clamped midway across a span of 3¾ inches on wood blocks. These panels were prismatic in detail having a minimum cross section of ⅛-inch and a maximum of ¼-inch over-all. Three plastic materials were investigated, two of which were different compoundings of methylmethacrylate, the third a poly carbonate material plus one borosilicate glass material.

The test was arranged such that the test weight struck the center of the test panel. In each case, the test was started at 16.5 inches with each successive impact being from a height greater by successive six-inch increments until failure of the specimen was observed.

Investigation was made to determine the fatiguing effect of repetitive impacts at successively greater heights by determining a basic height at which failure might occur and impressing the pellet from that height onto a new test panel. The difference was found to be small and for practical purposes, insignificant.

These test panels shown in comparison in Fig. 2 would indicate, generally, that the plastic media surpasses glass as a resistant material to impact breakage. It appears that either acrylic material has a minimum impact value which is equal to the maximum value found for borosilicate glass panels or on an average basis, approximately 2.1 to 2.3 times as resistant to breakage as glass. The poly carbonate panels showed no damage at 5 ft-lb impact or in excess of 13 times the impact strength of borosilicate glass. These comparisons are real and valid for flat panels. These are also very

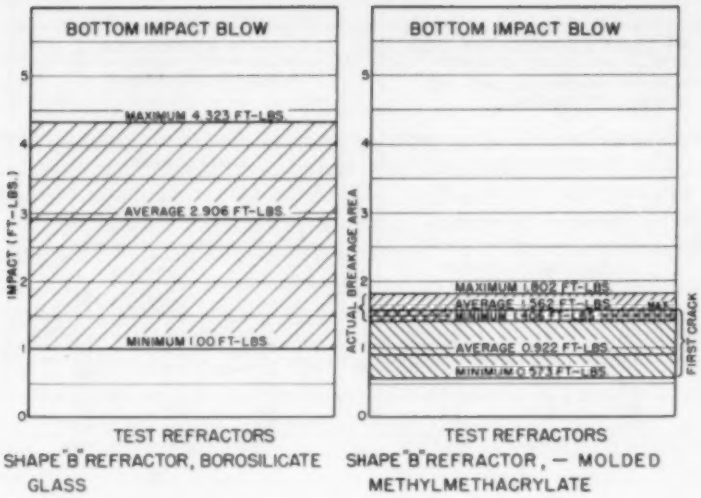

Figure 3. Impact comparisons between glass and plastic molded refractors. Direction of impact is perpendicular to opening of refractor flange.

common comparisons and can be expanded to cover nearly any application using a plastic material as compared to glass.

In comparing the strengths of acrylic and glass as molded, usable shapes, we used refractors which are duplicates, physically and optically, for impact testing. This allowed direct comparison between acrylic and borosilicate glass in actual pieces which are currently in use, and will give valid data as to impact resistances of the two materials. First, this comparison was made, taking as a particularly vulnerable direction of impact, that direction which is perpendicular to the opening of the refractor flange or normal to the axis of the refractor. Since all modern refractors are gasketed, we provided like support, for even under impact the refractor in use has this cushion. The impact comparisons are shown in Fig. 3. As can be seen, two sets of data are included for the acrylic refractors. A set of values is shown for the point at which the acrylic refractor first cracked, since really this is where the refractor first exhibited "breakage."

A second set of values indicates the higher levels of impact where the refractor was actually pierced (*i.e.*, a hole was produced by impact). In this set of values, the strength of acrylic does not compare so favorably as it had previously in the flat panels. Noteworthy, however, is the fact that when the glass refractors broke, they shattered, whereas the acrylic refractors were not destroyed even when holes were punched through them. The usefulness of acrylic refractors does not end when the refractors break.

When this comparison is made again, as shown in Fig. 4, but providing an impulse at 45 degrees to the refractor axis, another set of values becomes evident. The evidence still indicates an apparent superiority of borosilicate glass over acrylic so far as breakage itself is concerned, but in this area, the margin is reduced and the fact remains as to

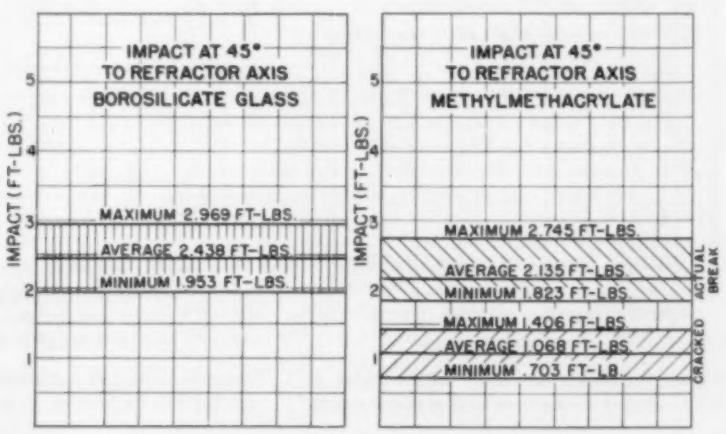

Figure 4. Impact comparisons between glass and plastic molded refractors with direction of impact at an angle of 45 degrees to refractor axis.

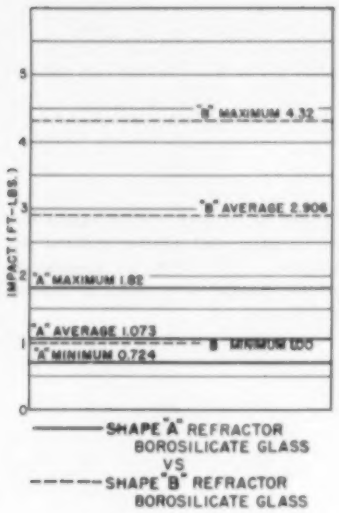

Figure 5.

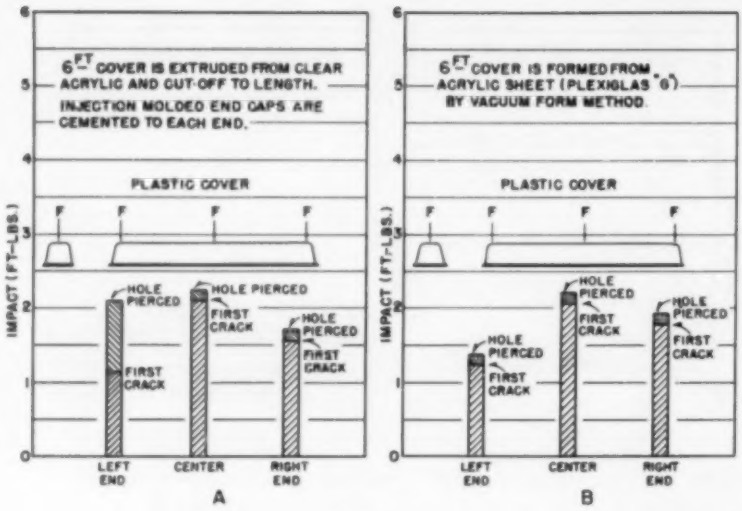
6 FT COVER IS EXTRUDED FROM CLEAR ACRYLIC AND CUT-OFF TO LENGTH. INJECTION MOLDED END CAPS ARE CEMENTED TO EACH END.
6 FT COVER IS FORMED FROM ACRYLIC SHEET (PLEXIGLAS "G") BY VACUUM FORM METHOD.
PLASTIC COVER
F
IMPACT (FT-LBS.)
HOLE PIERCED
FIRST CRACK
LEFT END
CENTER
RIGHT END
A
B

Figure 6.

how these two materials break and their usefulness afterward.

Product design contributes greatly to the inherent impact strength of an enclosing refractor, as shown in Fig. 5. This comparison is made using two refractors of identical material, but completely dissimilar shapes. It becomes apparent that the designer must pay some attention to the structural shape as well as the choice of material wehn designing transmitting enclosures for outdoor lighting. This comparison is shown, not to prove a point so far as material is concerned, but only to point out that a material cannot be penalized merely because of a weak structural design.

Fig. 6 presents a further comparison of the relative impact strengths of two 6-foot plastic covers which are fabricated by dissimilar methods. Fig. 6a represents a plastic cover which is an extruded shape, of clear acrylic, .125 thick, and cut off to length. The end closures are made by cementing on injection molded acrylic end caps. Fig. 6b represents a plastic cover which is one complete integral shape formed from cast acrylic sheet by the vacuum assist method over a male form. (Average thickness of .125.) The edge flange is then cut to size by saying off the excess.

The impact blows on this test were directed against the bottom surface with three points being tested along the length. It is significant to note that an area such as the center, where the plastic has the greatest flexure, is also the point of greater resistance to initial cracking and subsequent break-

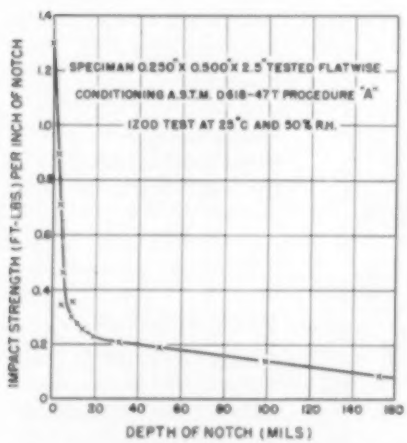
IMPACT STRENGTH (FT-LBS.) PER INCH OF NOTCH
SPECIMAN 0.250"X 0.500"X 2.5" TESTED FLATWISE
CONDITIONING A.S.T.M. D618-47T PROCEDURE "A"
IZOD TEST AT 23°C AND 50% R.H.
DEPTH OF NOTCH (MILS)

Figure 7. Notch sensitivity of Plexiglas II UVA, impact strength vs milled notch depth.

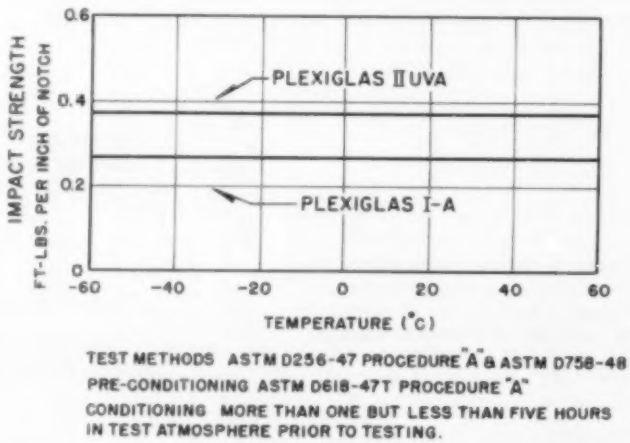
IMPACT STRENGTH FT-LBS. PER INCH OF NOTCH
PLEXIGLAS II UVA
PLEXIGLAS I-A
TEMPERATURE (°C)
TEST METHODS ASTM D256-47 PROCEDURE "A" & ASTM D758-48
PRE-CONDITIONING ASTM D618-47T PROCEDURE "A"
CONDITIONING MORE THAN ONE BUT LESS THAN FIVE HOURS IN TEST ATMOSPHERE PRIOR TO TESTING.

Figure 8. Effect of temperature on impact strength of Plexiglas I-A and II UVA, ¼ inch by ½ inch by 2½ inches IZOD milled notch bar.

age. The two ends present a more rigir member and fail at lower values. This flexural property of plastic is an important point to consider in luminaire design and application.

It is interesting to note the favorable comparison of resistance to impact between the two covers. Although the fabrication method are dissimilar, the ultimate physical properties are comparable.

Plastic or glass breakage often can be related to some prior inflicted scratch or marring of the surface. Fig. 7 shows, graphically, the results of tests made by Rohm and Haas on the "notch sensitivity" of acrylic panels. A significant fact, shown in Fig. 7, shows that a "notch" of a few thousandths in depth very appreciably reduces the foot-pound force required to initiate breakage. Glass refractors and shapes are also notch sensitive, which may reduce breaking strength as much as 75 per cent corresponding to less than a 10-mil notch depth in Plexiglas.

It is extremely important that luminaire enclosures, whether plastic or glass, be handled with care in storage, transportation, installation and maintenance to eliminate scratches or other surface abrasion which is the greatest contributing factor toward ultimate failure.

Closely related to the impact strength of methlmethacrylate is the effect of temperature, according to popular belief. Common belief has it that at low temperatures all plastics (therefore, also methylmethacrylate) become very brittle and at elevated temperatures they become more and more resistant to impact brakage. This theory does not apply to all plastics as indicated in Fig. 8, prepared by the Rohm & Haas Company, which shows practically no change in impact strength over a wide range of temperatures for acrylics. No detrimental characteristic is produced in acrylic by use in low temperature outdoor lighting areas as a whole.

It must be concluded that, since acrylic enclosures or refractors are not truly unbreakable nor appreciably less susceptible to breakage than glass refractors at this time, their worthiness must be based on their stability during thermal shock conditions and the fact that when breakage does occur, they do not shatter, but usually remain effective, whole and usable. This material then serves a great need today and with its increasing acceptance appears to be the beginning of a plastic era in outdoor lighting, particularly in view of the advancements made recently in the development of high temperature, extremely high strength, and economical plastics which appear capable of being refined to clear, high transmission materials.

DISCUSSION

H. A. Williams:* The growing use of acrylic plastics in outdoor lighting makes this paper very timely. I agree that luminaire enclosures, be they glass or plastic, should be handled with care. It is true that there is a tendency to feel that plastic items can withstand any degree of careless handling.

The authors' impact data on molded acrylic refractors, however, seem to be low in comparison to test history our laboratories have accumulated with molded parts. Because of this difference, I would like to ask the authors the following questions:

(1) In testing glass refractors vs. molded plastic refractors, did both refractors have the same maximum and minimum wall thicknesses?

(2) In the case of the impact tests on the molded acrylic refractors, did this test work involve a great many samples from a large production run? My reason for raising this question is that from experience it has been found that an experimental run may give parts having considerable variation in physical properties. On the other hand, after the injection molding conditions have been stabilized, such as would be the case on a large production run, the parts produced will have optimum and uniform physical properties.

(3) Mention was made of the reduction in strength of methyl methacrylate due to notch sensitivity and an example sited of a 75 per cent reduction by a notch 10 mils in depth. Do the authors have comparable data regarding the notch sensitivity of glass?

*Rohm & Haas Co., Plastic Department, Philadelphia, Pa.

H. A. Odle:* The several outdoor plastic refractors recently introduced for mercury and incandescent sources make it essential that the public in general, and particularly the people in the lighting profession, be informed as to the advantages and disadvantages of plastic for this application. The authors' tests provide some interesting and enlightening facts.

The new plastic refractors are made of methymethacrylate (commonly called acrylic), the best material presently available. Our utopian aim for a plastic is to have it as transparent as glass (which acrylic is) and as tough as steel. In other words, we would like a transparent stainless steel. No such material exists, of course, but the authors point out that acrylic does have some properties, such as crystal clarity, light weight, and breakage resistance, that make it compare favorably with glass for many sets of conditions.

Unfortunately, however, when too much heat is applied to acrylic it melts. For this reason, as Table I indicates, a luminaire rated at 400 watts with a borosilicate glass refractor must be derated to 250 watts when a plastic refractor of identical size and shape is used. Similarly, a 250-watt glass refractor unit becomes a 175-watt unit in plastic.

The newer polycarbonates show promise of being the answer to the problem of standing as much heat as glass and at the same time being highly impact resistant; unfortunately, the optical transmission is not yet good enough for use as a refractor material. In addition, the cost is, at present, 2½ to 3 times that of acrylic.

*Holophane Co., Inc., Newark, Ohio.

Fig. 2 shows the results of impact tests on flat panels. We have made impact tests similar to these (using a two-pound pellet) and they check the results of Fig. 2 rather closely. However, when the panels were static loaded, we found the glass about twice as strong as plastic. A test with a heavy pellet (five pounds) yielded results between those for static loading and those for the small two-pound pellet. It seems reasonable to assume, then, that velocity (*i.e.*, size of pellet used to produce a given ft-lb impact) is a factor which would influence Fig. 2 (also Figs. 3 and 4), and it appears that the smaller the pellet used to break the samples, the more favorably the plastic would show up.

The authors seem to feel that the main advantage of plastic refractors over glass is the fact that plastic does not shatter when punctured by a blow and therefore does not necessarily end its usefulness or cause damage. It appears that an argument could also be made for the lighter weight of plastic during the initial installation and subsequent washings. It would be interesting to know whether maintenance companies are as yet taking this factor into account.

There are two other points in which the lighting public should be extremely interested. First, operating data are needed on dirt accumulation of plastic *vs.* glass. The second point is the resistance to abrasion of plastic *vs.* glass, both by cleaning and by wind-driven abrasives. Perhaps the authors will present these data in a future paper.

D. E. Husby and M. R. Anderson:* There is no question that the utopian material would have the characteristics of transparent stainless steel. The question becomes one of proper education for the general user. Plastic materials, whether they be acrylic or other transparent media, are too often pictured or colored by the vendor as being very much like the utopian material. We believe that we have shown a little of what must be considered common fact about plastic materials.

The impact data shown does illustrate low values for molded acrylic refractors as compared to glass refractors. Here the consideration must be taken to end usable shapes. If the acrylic refractors had the same minimum and maximum wall thicknesses as their counterparts in glass, the cost per unit plastic would be much too high for practical use. After all, the base price per pound of the two materials is quite different.

One of the advantages of plastics, as compared to glass, is that it can be molded into thinner wall sectioned products. As pointed out in the paper, acrylic has many definite advantages of application if proper limitations be recognized. Of the present-day materials, only acrylic can do as much in fulfilling the complete set of requirements imposed by the outdoor lighting industry.

The question of the influence of velocity in the determination of impact strengths of glass *vs.* plastic (acrylic) brings into play the physical size as well as mass of the impinging article. It is felt that as long as the surface-contact-area is kept constant between various sizes of pellet mass, values such as those which appear in Fig. 2 will be substantiated.

Perhaps the indicated increase of impact strength with the corresponding increase of pellet size can be explained in the following manner. Suppose the pellet size, in area of contact, were reduced to the point where the area contact becomes a point contact—would not the glass media tend to chip and break away at values where the plastic media would only deflect slightly due to its lower modulus?

It is hoped that the comments of the discussers have instigated questions in the minds of others, so that plastic's properties will be more accurately sold and utilized. These are truly remarkable materials if used properly.

*Authors.

Private Airplane Hangar

National Distillers & Chemical Corp. hangar at Teterboro Airport, Teterboro, N. J., is lighted by 10 rows of twin prismatic reflector mercury luminaires, four twin units per row. Fixtures are equipped with 400-watt H33-1-GL/C improved-color fluorescent mercury lamps and two-lamp constant-wattage ballasts. Mounting is on 20-foot centers at a height of 30 feet. Maintained lighting level averages 45 footcandles on the work plane which extends 25 feet up from the floor, from landing gear to vertical stabilizer of plane. High reflectance of floor assures adequate lighting for repairs and servicing on underside of wing, without the need for any supplementary illumination.

Lighting designed by Frank Merlino, John C. Morris Co., Jersey City, N. J.

Roadway Brightness and Illumination As Related to Luminaire Distributions

By ARTHUR W. FOWLE
RICHARD L. KAERCHER

Instead of specifying only light/brightness values for roadway lighting, the authors propose the development of application charts to be derived from a series of system data for pavement brightness, obstacle brightness, veiling brightness and illumination values, plotted vs. varying street width and spacing conditions to enable the over-all quality of the installation to be judged.

MOST STREET LIGHTING engineers have probably heard a number of expressions of the need for adequate pavement brightness data from which a standard might be developed for lighting (or "brightening") of roadways. The authors were made quite aware of the widespread interest in this when a previous paper[1] recommended that horizontal footcandles together with uniformity of horizontal footcandles be used as the most practical single criterion because of the ease of calculating results on horizontal road surfaces.

Many expressed their opinion then, and others later, that classifications for roadway lighting should be based solely on brightness values of the roadway, on the apparent assumption that we see by brightness and not by illumination. Some even believe the footcandle to be hopelessly outmoded and feel that this standard for specifying a roadway lighting system should be abandoned entirely.

The purpose of this paper is to discuss both footcandles and footlamberts as related to the problem of proper roadway lighting. There is no intent to prove an incompability of one criteria with the other. Instead, it is hoped the paper will disclose some additional facts about the many complex relationships between illumination, road brightness and distribution of light flux from the luminaires in roadway lighting systems.

There is, of course, a definite relationship between footlamberts brightness and footcandles illumination because, before a surface can appear bright (by reflected flux), there must have been light flux directed to the surface. Evaluating these relationships is by no means a new problem. It was so well stated back in 1914 by Dr. C. H. Sharp, in a discussion[2] of a paper by Dr. H. Ives, that it bears repeating here: "It should be emphasized that brightness data and illumination data cannot be made to replace each other. They ca nonly supplement each other. The illumination data show only the light flux received and give, only by implication or interpretation, an idea of how bright the surfaces receiving it appear. Brightness data, on the other hand, show how actual natural objects look in a given case and do not show how much illumination has been required to produce the observed effect."

Perhaps little more than this needs to be said, except there is still the question—in what manner does the distribution of light flux directed to the roadway influence the roadway brightness, and how might this brightness data be used for specifying roadway conditions once it becomes available? Proposals have been made simply to substitute an average footlamberts brightness value in place of an average horizontal footcandle value, based on a well selected multiplying factor, that would convert one to the other. One example of where this has been done is in the "Recommendation on Public Lighting" prepared by the Netherlands Foundation on Illumination.[3] In these recommendations an average factor was developed and when converted to our system of units becomes a Footlambert/Footcandle factor of 0.217. This is based on the results of a large number of measurements of illumination and brightness of several systems with customary dry road surfaces used in the Netherlands. The type of luminaire used was fairly uniform with respect to light distribution, generally being a "cut-off" type. It was felt that an average conversion factor was justified for this purpose, at least for important traffic routes where this type of luminaire is used.

A similar factor could be developed here by taking many types of systems and averaging the ratios of Footlamberts/Footcandles for each system. The

A paper presented at the National Technical Conference of the Illuminating Engineering Society, September 11-16, 1960, Pittsburgh, Pa. AUTHORS: Holophane Co., Inc., Newark, Ohio.

authors did not have facilities for making measurements, as was done in the Netherlands, but did investigate this relationship using the calculation method for several different types of lighting systems and light distributions. To obtain these data many point by point calculations of individual brightness values contributed by all significant luminaires in the system were required. The brightness values were calculated using the Reid-Channon pavement reflectance data,[4] the only complete data available at this time. The eye level height and observer position with respect to the pavement brightness location was similar to that shown in Fig. 1 except for a variety of system arrangements. The over-all average brightness results obtained for each type of luminaire, lamp and system combination, together with the resultant average footcandles are shown in Table I. The computed Ratio of Average Footlamberts/Average Footcandles is also shown for each case.

The average of all of the Footlambert/Footcandle factors for the first 17 systems is 0.285. This figure is a weighted average which is dependent upon the number of different types of systems used in making a table of this type. Nevertheless, there seems to be a relationship between road brightness and road illumination that could easily lead to the premise that a brightness value could be substituted for the average horizontal footcandle value now used in roadway lighting practice.

The range of Footlambert/Footcandle factors for the examples used are as much as 3 to 1 between the lowest and the highest value. There is a reason for this. In order to explain this variation it is necessary to examine the various components that affect the relationship between brightness and illumination. These data differ from that obtained by the Netherlands study in that there is a wide range of vertical distributions involved, in line with the general practice in this country. The range is from quite "low vertical angle" to "high vertical angle" distributions. Table I indicates that the low angle type of distribution generally seems to produce the smallest ratio factor or the smallest average footlamberts brightness per average horizontal footcandle. On the other hand, the high angle distributions generally produce the largest ratio of average footlamberts per average horizontal footcandles. This is the result that might be expected on the basis that the higher emission angle light flux is worth more in producing pavement brightness than flux at lower emission angles, all other things being equal.

This relationship was further explored in a special study in systems 18 through 29. Both pendant incandescent and horizontal mercury luminaires were tested with different light center settings to produce different vertical angles of maximum candlepower. The average illumination level lowered slightly as the vertical angle raised but, at the same time, the average roadway brightness increased. The resulting Footlamberts/Footcandles ratio factor increased as the vertical angle increased. This same relationship held for both types of luminaires and two different spacing conditions.

If this were a direct relationship in all cases it might be possible to class the different light distribution patterns into some type of "low," "high" and "medium" category, with an appropriate multiplying factor applying for each one.

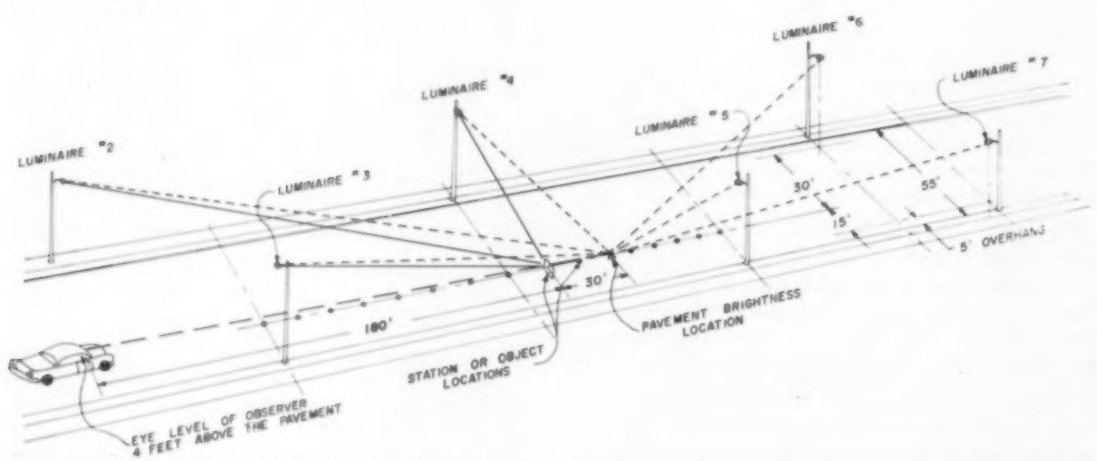

Figure 1. Layout of roadway lighting systems No. 18 through 29 showing observer position with respect to brightness location and contributing luminaires. This layout also refers to contrast data computed for Figs. 2, 3 and 4, showing object station in relation to observer and pavement brightness location.

TABLE I—Average Horizontal Illumination and Pavement Brightness Results from Several Lamp and Luminaire Combinations and Different Roadway Lighting Systems.

System No.	Luminaire and Lamp	Spacing	Vertical Angle of Maximum Candlepower	Average Horizontal Illumination fc	Average Pavement Brightness fL	Ratio fL/fc	Uniformity Footcandles	Uniformity Footlamberts
1	Small Enclosed 2500-Lumen Filament	220′	77½°	.093	.038	.41	2.9/1	2.0/1
2	Open Asymmetric 2500-Lumen Filament	220′	72°	.13	.039	.30	13.0/1	2.0/1
3	Small Enclosed 2500-Lumen Filament	160′	77½°	.13	.05	.38	1.9/1	1.6/1
4	Small Horizontal 175-Watt Mercury	160′	79°	.615	.162	.264	2.9/1	1.9/1
5	Small Horizontal 175-Watt Mercury	160′	75°	.72	.13	.18	3.3/1	2.6/1
6	Open Asymmetric 2500-Lumen Filament	160′	72°	.20	.055	.275	5.0/1	2.1/1
7	Radial Wave 2500-Lumen Filament	120′	0°	.20	.05	.25	3.3/1	1.7/1
8	Medium Pendent 6000-Lumen Filament	120′	74°	.50	.14	.28	1.9/1	1.6/1
9	Medium Pendent 6000-Lumen Filament	120′	78°	.47	.24	.51	1.5/1	1.6/1
10	Medium Pendent 6000-Lumen Filament	300′	77°	.20	.055	.275	5.0/1	2.1/1
11	Horizontal Mercury 400-Watt Clear Mercury	120′	75°	1.32	.407	.308	2.8/1	—
12	Parallel Fluorescent 2-Lamp	120′	45°	.75	.127	.17	4.8/1	—
13	Transverse Fluorescent 4-Lamp	120′	55°	.973	.239	.246	5.5/1	—
14	Parallel Fluorescent 2-Lamp	75′	45°	1.04	.183	.175	—	1.4/1
15	Transverse Fluorescent 2-Lamp	75′	62½°	.56	.145	.26	—	1.1/1
16	Horizontal Mercury 700-Watt Improved-Color	140′	67°	1.98	.53	.268	3.2/1	1.8/1
17	Horizontal Mercury 700-Watt Improved-Color	140′	67°	1.74	.50	.289	2.6/1	1.7/1
Medium Pendent 6000-Lumen Filament:								
18	Low Angle	140′	66°	.45	.092	.204	3.0/1	1.3/1
19	Medium Angle	140′	73°	.39	.103	.264	2.5/1	1.4/1
20	High Angle	140′	77½°	.35	.106	.33	3.0/1	1.3/1
21	Low Angle	180′	66°	.32	.071	.222	6.6/1	1.9/1
22	Medium Angle	180′	73°	.30	.079	.264	3.5/1	1.5/1
23	High Angle	180′	77½°	.27	.081	.30	3.5/1	1.3/1
Horizontal Mercury 400-Watt Clear:								
24	Low Angle	140′	69°	1.61	.344	.214	4.3/1	1.9/1
25	Medium Angle	140′	74°	1.50	.373	.249	3.8/1	1.8/1
26	High Angle	140′	77°	1.37	.398	.291	3.3/1	1.5/1
27	Low Angle	180′	69°	1.36	.265	.195	5.5/1	2.0/1
28	Medium Angle	180′	74°	1.17	.289	.247	3.9/1	1.7/1
29	High Angle	180′	77°	1.07	.309	.289	3.6/1	1.5/1

With such factors available, it would be possible to determine, quickly, the average footcandles needed to produce the required average pavement brightness condition when the type of vertical distribution is known. However, this is not the only modifying influence on the relationship of footlamberts to footcandles.

There is also the complex situation by which light flux at different vertical angles produces varying amounts of roadway brightness. A given light distribution in one case may have considerably more light flux in one vertical zone than another light distribution, although both may have maximum candlepower at the same vertical angle and even the value of maximum candlepower might be the same.

The distribution with greater flux content at the higher vertical angles, with all other zones being equal, will produce greater pavement brightness average. On the other hand, a distribution with equal flux content in the upper zones but greater flux in the lower zone will also produce greater average brightness.

Another modification comes from different types of pavement surfaces used, some more diffuse than others. The diffuse surfaces are not as responsive to high angle light flux as the more specular surfaces. The paper by Ruff and Lambert[5] presents a wide variety of pavement reflection factors for different pavement surfaces. The sensitivity to high angle illumination appears to have a range of almost 100 to 1 at near grazing angles, that is,

TABLE II—Typical Pendant Filament Luminaire, IES Type III, With 6000-Lumen Street Series Lamp, 140-Foot Staggered Spacing. Data from Systems 18, 19 and 20, For One Longitudinal Roadway Line.

Station	Low Angle 66 Degrees					Medium Angle 73 Degrees					High Angle 77½ Degrees				
	B_1	B_2	B_v	C′	E_h	B_1	B_2	B_v	C′	E_h	B_1	B_2	B_v	C′	E_h
1	.068	.0096	.0035	.817	.61	.080	.012	.0085	.768	.60	.098	.0136	.0235	.695	.52
2	.070	.0372	.004	.443	.57	.084	.0332	.010	.540	.48	.0895	.0312	.0255	.507	.44
3	.070	.0564	.005	.315	.41	.093	.0371	.012	.532	.35	.0885	.0326	.0295	.474	.30
4	.0695	.0316	.006	.502	.25	.081	.0334	.016	.491	.28	.085	.0248	.0335	.508	.22
5	.072	.0165	.009	.685	.23	.072	.0226	.022	.526	.28	.087	.0186	.038	.547	.21
6	.077	.0074	.0125	.777	.34	.079	.0136	.028	.611	.28	.098	.0128	.040	.617	.28
7	.080	.0028	.0105	.853	.61	.091	.0074	.021	.746	.48	.110	.0083	.031	.721	.46
8	.0835	.0132	.0025	.817	.89	.1095	.0105	.008	.843	.51	.114	.0124	.0205	.755	.50
9	.103	.0406	.0035	.586	.61	.139	.0328	.010	.713	.48	.1255	.0320	.023	.630	.46
10	.133	.0378	.0035	.697	.34	.163	.0342	.0115	.738	.28	.133	.0298	.024	.657	.28
11	.1545	.0270	.004	.804	.23	.152	.0326	.014	.719	.28	.1295	.0248	.027	.669	.21
12	.1415	.0152	.0065	.853	.25	.121	.0220	.016	.723	.28	.1175	.0204	.032	.649	.22
13	.096	.0082	.010	.823	.41	.095	.0134	.0195	.713	.35	.107	.0156	.037	.635	.30
14	.074	.0034	.007	.872	.57	.087	.007	.014	.792	.48	.111	.0118	.034	.684	.44
15	.068	.0096	.0035	.817	.61	.080	.012	.0085	.768	.60	.098	.0136	.0235	.695	.52
Avg.	.092	.0212	.0063	.703	.45	.103	.0223	.0150	.675	.39	.1067	.0206	.0299	.625	.35
Unif.	1.35/1	2.57/1	2.52/1	2.23/1	1.96/1	1.43/1	3.19/1	1.88/1	1.37/1	1.39/1	1.26/1	2.48/1	1.46/1	1.32/1	1.67/1

the most responsive types will produce 100 times more brightness per footcandle than the least responsive types. On the other hand, at that point on the pavement where the lower emission angles are effective, the reverse is true, and the diffuse type pavement produces more brightness per horizontal footcandle than the more specular pavement.

Since the average Footlamberts/Footcandles factor is obtained by averaging several points on a roadway, each of which receives illumination from different angles, the low, medium and high angle distributions will produce a different range of results on different pavements. Also, the variable amounts of light flux above and below maximum, with different luminaire and lamp combinations, will further contribute to widening the range of Footlamberts/Footcandles factors.

Spacing of luminaires and other parts of the system geometry will also influence the Footlamberts/Footcandles ratio factor. For example, ratio values were computed at different spacing conditions for some of the distributions in Table I. In some cases, the factor increased as the spacing increased; in other cases the reverse was true. There was not enough statistical data here to come to any conclusion except that it is probably a minor influence on the ratio factor.

If all of the constituents of the relationship between candlepower distribution, roadway brightness and average horizontal footcandles are considered, it becomes too complex to define and therefore difficult to give exact meaning to a single ratio factor. It might eventually be possible to establish a category for all influencing elements and develop, by an enormous amount of calculations, a ratio factor applying to each case. However, this ratio factor would still simply be a means of transferring an average roadway horizontal illumination value to an average roadway brightness value or vice versa.

Up to this point the discussion has been confined to the relationships between pavement brightness and horizontal illumination. Neither of these will provide a means of determining the seeability in

TABLE III—Typical Pendant Filament Luminaire, IES Type III, with 6000-Lumen Street Series Lamp, 180-Foot Staggered Spacing. Data from Systems No. 21, 22 and 23, For One Longitudinal Roadway Line.

Station	Low Angle 66 Degrees					Medium Angle 73 Degrees					High Angle 77½ Degrees				
	B_1	B_2	B_v	C′	E_h	B_1	B_2	B_v	C′	E_h	B_1	B_2	B_v	C′	E_h
1	.061	.0008	.0035	.933	.60	.057	.0024	.0098	.817	.58	.063	.0036	.013	.782	.49
2	.052	.037	.0045	.265	.55	.056	.0312	.0099	.376	.46	.062	.0288	.0145	.434	.41
3	.0415	.044	.005	.054	.39	.055	.0348	.0120	.301	.31	.065	.0294	.016	.440	.26
4	.0395	.032	.006	.165	.19	.060	.0328	.015	.363	.21	.067	.0240	.020	.494	.16
5	.049	.016	.007	.589	.10	.068	.0486	.020	.220	.14	.069	.0164	.025	.560	.13
6	.060	.0072	.011	.744	.09	.063	.0130	.027	.556	.14	.070	.0112	.032	.576	.13
7	.067	.0028	.010	.834	.16	.056	.0076	.017	.663	.21	.071	.0080	.022	.677	.16
8	.062	.0012	.002	.950	.32	.063	.0040	.0051	.866	.24	.073	.006	.011	.798	.25
9	.052	.0006	.003	.935	.60	.064	.0022	.0052	.893	.46	.079	.004	.011	.833	.43
10	.057	.0056	.003	.857	.40	.060	.0016	.0095	.840	.50	.075	.0089	.013	.751	.48
11	.048	.040	.0035	.155	.60	.068	.0308	.010	.477	.46	.082	.030	.0135	.545	.43
12	.054	.0378	.004	.279	.32	.093	.0280	.010	.631	.24	.092	.0288	.017	.580	.25
13	.080	.264	.0045	.634	.16	.122	.0324	.013	.664	.21	.1075	.0230	.0235	.645	.16
14	.117	.0144	.0055	.838	.09	.143	.0212	.015	.771	.14	.1185	.0198	.0265	.681	.13
15	.147	.0082	.009	.890	.10	.138	.0132	.018	.800	.14	.1135	.0149	.029	.692	.13
16	.136	.0034	.0075	.924	.19	.113	.0072	.015	.827	.21	.102	.0103	.023	.734	.16
17	.089	.0014	.0025	.957	.39	.086	.0048	.007	.873	.31	.083	.007	.014	.784	.26
18	.069	.0008	.0025	.954	.55	.065	.0028	.0085	.846	.46	.069	.0052	.012	.788	.41
19	.061	.0008	.0035	.933	.60	.057	.0024	.0098	.817	.58	.063	.0036	.013	.782	.49
Avg.	.071	.0155	.0052	.664	.32	.079	.0177	.0126	.655	.30	.081	.0155	.0187	.655	.27
Unif.	1.80/1	25.8/1	2.60/1	12.3/1	3.56/1	1.41/1	11.06/1	2.47/1	2.98/1	2.14/1	1.31/1	4.31/1	1.70/1	1.51/1	1.08/1

TABLE IV—Typical Horizontal Mercury Luminaire, IES Type III, with 400-Watt H1LS (E-H1) Clear Mercury Lamp, 140-Foot Staggered Spacing. Data from Systems No. 24, 25 and 26, For One Longitudinal Roadway Line.

Station	Low Angle 69 Degrees					Medium Angle 74 Degrees					High Angle 77 Degrees				
	B_1	B_2	B_v	C'	E_h	B_1	B_2	B_v	C'	E_h	B_1	B_2	B_v	C'	E_h
1	.220	.0076	.013	.912	4.27	.315	.0214	.030	.851	3.74	.318	.0357	.098	.679	3.68
2	.260	.1664	.016	.339	2.15	.257	.1540	.040	.347	2.04	.308	.1195	.110	.451	1.87
3	.290	.1366	.016	.501	1.02	.220	.1512	.053	.252	1.17	.302	.1395	.121	.384	1.01
4	.218	.1259	.023	.382	1.01	.222	.1037	.076	.400	.71	.294	.1066	.133	.439	.73
5	.192	.0858	.040	.458	.85	.275	.0779	.099	.527	.62	.312	.0719	.156	.513	.60
6	.308	.0444	.062	.713	.87	.365	.0557	.110	.651	.90	.418	.0520	.183	.609	.74
7	.332	.0160	.041	.847	1.64	.415	.0390	.069	.777	1.90	.468	.0422	.125	.718	1.53
8	.282	.0079	.011	.935	3.13	.410	.0240	.028	.881	2.57	.400	.0326	.080	.765	2.60
9	.438	.1095	.014	.727	1.64	.463	.1080	.035	.713	1.90	.406	.1162	.097	.576	1.53
10	.528	.0888	.015	.809	.87	.482	.1086	.038	.718	.90	.454	.0842	.104	.663	.74
11	.482	.0921	.019	.778	.85	.462	.1047	.053	.694	.62	.461	.0697	.119	.590	.60
12	.405	.0927	.029	.720	1.01	.438	.1065	.091	.627	.71	.459	.0655	.129	.669	.73
13	.486	.0314	.040	.864	1.02	.468	.0523	.096	.737	1.17	.528	.0498	.131	.726	1.01
14	.368	.0159	.030	.885	2.15	.426	.0284	.055	.827	2.04	.450	.0462	.111	.721	1.87
15	.220	.0076	.013	.912	4.27	.315	.0214	.030	.851	3.74	.318	.0357	.098	.679	3.68
Avg.	.344	.0729	.026	.705	1.61	.373	.081	.062	.643	1.50	.398	.0737	.121	.607	1.37
Unif.	1.8/1	9.6/1	2.36/1	2.08/1	1.9/1	1.7/1	3.8/1	2.2/1	2.55/1	2.4/1	1.35/1	2.26/1	1.51/1	1.58/1	2.28/1

a roadway lighting system since seeing is a matter of brightness *contrasts*. These are, however, part of the data needed to compute the ability of the system to reveal an object in contrast with its pavement background. In order to further study the relationships of pavement brightness and illumination, the apparent contrast, C', of an object silhouetted against the pavement was computed for all of the systems 18 through 29 listed in Table I, using the formula:[6]

$$C' = \frac{B_1 - B_2}{B_1 + B_v}$$

Where: B_1 = Pavement Brightness, in footlamberts, behind the object

B_2 = Brightness of a standard test object, in footlamberts, having a reflection factor of eight per cent

B_v = Disability veiling brightness, in footlamberts (from luminaires only)

The object was set up as shown in Fig. 1 and moved down the roadway in 20-foot steps. Object brightness, B_2, was obtained by multiplying the vertical footcandles, E_v, by eight per cent. All brightness values, together with the resultant contrasts, C', and the related horizontal footcandle values along the line shown in Fig. 1 are tabulated in Tables II through V.

Three typical sets of these data have been plotted in Figs. 2, 3 and 4, showing the results of a low, medium and high angle vertical distribution. There are some interesting relationships here. The highs and lows of C' do not necessarily follow those of pavement brightness, B_1, all the way through the system. In fact, the relation of E_h and C' seems to be somewhat closer. Actually C' is related to the differences between B_1 and B_2 rather than B_1 alone. B_2 is directly proportional to E_v. There is no definite conclusion to be drawn except that E_h and B_1 and the other brightnesses are not directly related to each other, but all of them are used to obtain a more important and meaningful factor, C'.

This contrast value has not been introduced to represent a measure of effective visibility or visi-

TABLE V—Typical Horizontal Mercury Luminaire, IES Type III, with 400-Watt H1LS (E-H1) Clear Mercury Lamp, 180-Foot Staggered Spacing. Data from Systems No. 27, 28 and 29, For One Longitudinal Roadway Line.

Station	Low Angle 69 Degrees					Medium Angle 74 Degrees					High Angle 77 Degrees				
	B_1	B_2	B_v	C'	E_h	B_1	B_2	B_v	C'	E_h	B_1	B_2	B_v	C'	E_h
1	.184	.0025	.013	.921	4.24	.220	.0069	.030	.852	3.64	.250	.0175	.087	.690	3.57
2	.150	.1636	.013	.083	2.10	.202	.1469	.037	.231	1.88	.240	.1424	.097	.290	1.76
3	.140	.1351	.015	.032	.92	.220	.1471	.048	.272	1.03	.220	.1299	.109	.274	.92
4	.190	.1251	.022	.306	.65	.248	.1018	.069	.461	.60	.210	.1001	.122	.331	.59
5	.228	.0853	.035	.543	.43	.208	.0765	.090	.441	.55	.230	.0677	.124	.458	.40
6	.163	.0441	.060	.533	.54	.180	.0546	.101	.446	.48	.215	.0493	.122	.492	.40
7	.160	.0158	.040	.721	.57	.184	.0382	.070	.574	.51	.248	.0401	.095	.606	.44
8	.240	.0077	.006	.944	.74	.280	.0234	.018	.861	.69	.341	.0311	.051	.791	.64
9	.260	.0033	.009	.954	1.60	.315	.0126	.022	.897	1.54	.359	.0230	.059	.804	1.44
10	.150	.0022	.010	.924	3.10	.224	.0074	.022	.880	2.92	.280	.0171	.066	.760	2.52
11	.159	.1075	.011	.303	1.60	.258	.1044	.024	.545	1.54	.288	.1044	.071	.512	1.44
12	.242	.0876	.014	.603	.74	.340	.0838	.036	.681	.69	.328	.0755	.099	.591	.64
13	.396	.0915	.019	.734	.57	.406	.0732	.048	.733	.51	.358	.0636	.105	.636	.44
14	.460	.0922	.026	.757	.54	.413	.0717	.060	.712	.48	.388	.0610	.110	.657	.40
15	.420	.0311	.037	.851	.43	.400	.0754	.083	.672	.55	.407	.0465	.112	.695	.40
16	.382	.0157	.025	.900	.65	.400	.0383	.069	.706	.60	.390	.0439	.090	.721	.59
17	.470	.0076	.010	.963	.92	.402	.0213	.022	.898	1.03	.440	.0352	.068	.797	.92
18	.370	.0044	.012	.955	2.10	.298	.0111	.029	.877	1.88	.370	.0250	.078	.770	1.76
19	.184	.0025	.013	.921	4.24	.220	.0069	.030	.852	3.64	.250	.0175	.087	.690	3.57
Avg.	.265	.0568	.021	.668	1.36	.289	.0608	.049	.652	1.17	.309	.0596	.093	.604	1.07
Unif.	1.89/1	25.8/1	3.5/1	20.9/1	3.16/1	1.61/1	8.81/1	2.72/1	2.82/1	2.44/1	1.47/1	3.49/1	1.82/1	2.20/1	2.68/1

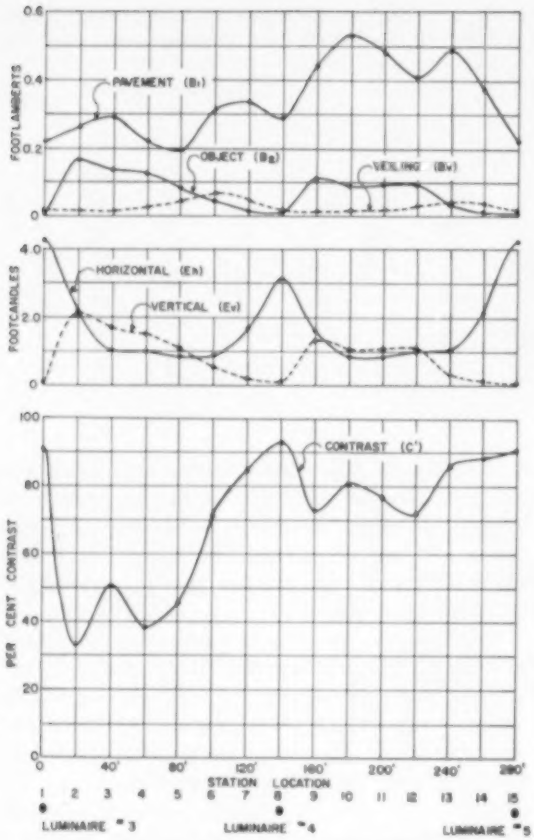

Figure 2. Pavement brightness, object brightness disability veiling brightness, vertical and horizontal illumination and contrast computed for different positions along one driving lane as illustrated in Fig. 1. Data are from System No. 24, horizontal 400-watt mercury, 140-foot spacing, low-angle distribution.

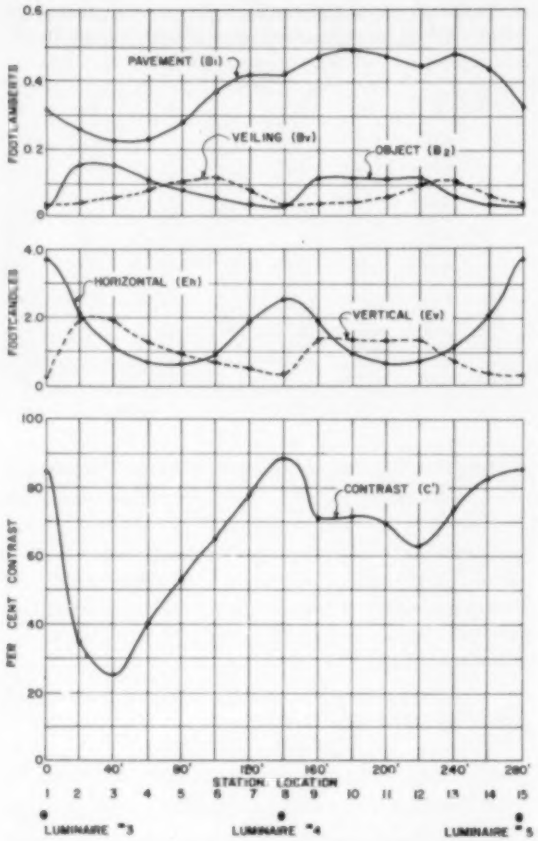

Figure 3. Pavement brightness, object brightness, disability veiling brightness, vertical and horzontal illumination and contrast computed for different positions along one driving lane as illustrated in Fig. 1. Data are from System No. 25, horizontal 400-watt mercury, 140-foot spacing, medium angle distribution.

bility distance because there is no indication of an obstacle size, exposure time, motion or any other extenuating factors that might apply in determining "visibility" by one means or another. It is, however, felt to be a value that relates the potential ability of one system with another in revealing the presence of an object on the roadway. Furthermore, the task of calculating these contrast values is perfectly straightforward, although time consuming, if the system design, light distribution and pavement characteristics are known.

If the object reflection factor were to be much higher than eight per cent, for example, on the order of 20 or 30 per cent, and the object were large enough to protrude above the horizon, it would not be seen in contrast against the pavement but against some darker surround such as sky, building fronts, etc. Here the pavement reflection factor would be of little value. The important data would be vertical footcandles on the object at some distance above the road surface and brightness of the surround.

No one can yet establish a particular condition of seeability or road brightness and determine the luminaire, lamp and system design necessary to obtain it. It is possible, however, to determine a horizontal footcandle level, and select conditions to produce a given uniformity ratio of illumination. While this is no guarantee of the seeability of a system, neither is any other illumination or brightness factor. They must all be considered together and carefully examined in relation to one another. The horizontal footcandle is the one element that can be readily computed and related to, or from, the horizontal geometry of the roadway lighting system. The quality aspects and refinements of a lighting system can be judged by examining the level and uniformity of illumination, as well as brightness of the roadway, level of veiling glare, etc. No one factor alone will give the true answer.

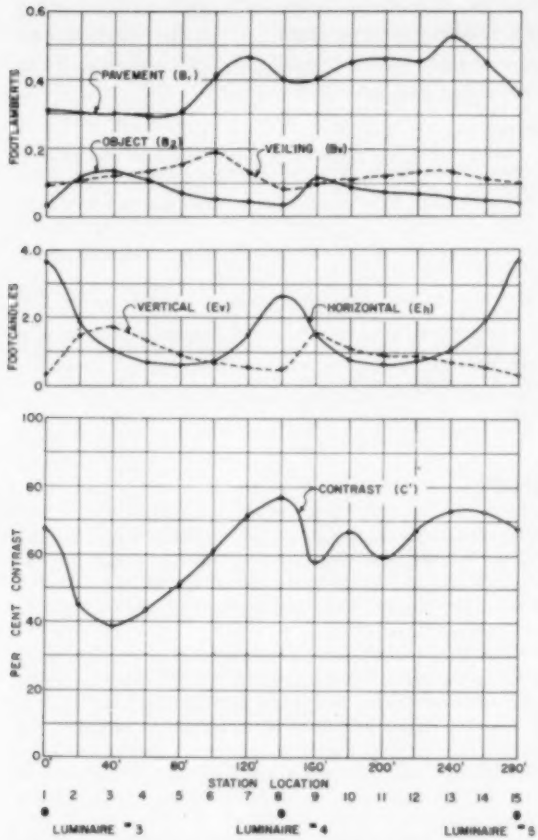

Figure 4. Pavement brightness, object brightness, disability veiling brightness, vertical and horizontal illumination and contrast computed for different positions along one driving lane as illustrated in Fig. 1. Data are from System No. 26, horizontal 400-watt mercury, 140-foot spacing, high angle distribution.

If a Footlambert/Footcandle factor were to be used in luminaire and system design, it would be necessary to explore all possible relationships to determine the effect each has on this ratio factor. This would be a highly impractical solution, since the end result would still be only a multiplying factor between footcandles and footlamberts.

Instead, it is suggested that a series of system data be developed for pavement brightness values and illumination values both near the road surface and at some height above the roadway from which obstacle brightnesses and veiling brightness can be calculated. These could be computed and plotted for varying spacing and street width conditions in the form of an application guide similar to that now used for footcandle level and uniformity ratio charts (Fig. 5). These are now used to relate different items of equipment, or light distributions and system designs to average horizontal footcandles and uniformity of illumination.

It is believed similar information on brightness data would be very helpful in assisting the application engineer in selecting various types of luminaires and light distributions for other system effects than horizontal illumination. Knowing, for example, that a particular kind of low angle or high angle distribution would produce different average levels of road brightness per system horizontal footcandle, the application engineer could apply this knowledge of the equipment accordingly.

If the application engineer is more concerned with higher levels of vertical illumination than with pavement brightness levels, then perhaps a different type of light distribution should be used. If he is concerned with reduction in disability veiling brightness (which will also improve the comfort aspect), then the proper cut-off type distributions would have to be considered. These, in turn, would have to be evaluated along with the other aspects of pavement brightness and vertical footcandles.

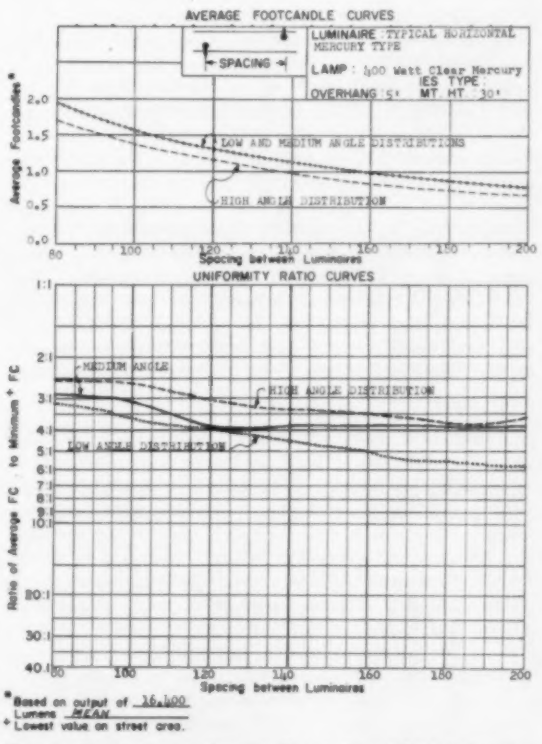

Figure 5. Average footcandle and uniformity ratio curves. These are plots of the illumination and uniformity ratio values computed for each spacing condition for a given system design. Data for several street widths can be plotted on one chart or, as in this case, data are shown for low, medium and high vertical angle distributions using same luminaire and street width. These curves are for the system represented by Figs. 2, 3 and 4.

The number of computations necessary for preparing such data explain, to some extent, why it has not been done before, but it is hoped this paper will show in a small way the value of eventually going further in this field. Obtaining such information can be facilitated by computer techniques and once obtained the data and charts can be used many times by design and application engineers. It would enable a comparison of the use of different light distributions in different system arrangements from the standpoint of, not only resultant horizontal footcandles and footcandle uniformity, but also pavement brightness and its uniformity, vertical illumination and its uniformity and system veiling brightness. This may further help to lead the way to the ultimate criterion of designing the lighting system according to the effect a particular light distribution will have on the ability to see under that system.

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DISCUSSION

HAROLD F. WALL:* We all know that visibility under street lighting conditions is comprised of many more things than just plain horizontal footcandles. There has been considerable discussion relative to specifying average pavement brightness for street lighting, and although this would seem to be one of the most important factors in visibility, there is as yet no commonly agreed upon method for calculating this average figure. It is entirely possible that the pavement brightness 210 feet in front of the observer might be excellent, resulting in perfect visibility, and yet the brightness 10 feet to the right or left of this location might be zero. We understand that the authors have averaged the brightnesses only of the locations 210 feet in front of the observer in one or more driving lines as described above, and we agree that this cannot fully represent seeability.

From this inadequate calculation of pavement brightness, however, the authors have calculated and introduced contrast as a visibility factor. A comparison of Tables II and IV, representing similar systems of street lighting except with 6000-lumen incandescent and 20,000-lumen mercury lamps, respectively, results in the impossible conclusion that the smaller incandescent lamp provides better visibility in the medium and high-angle distribution categories, inasmuch as the average contrast for the smaller lamps is numerically higher. This same inconsistency is exhibited in in Tables III and V.

More than ever it seems to me that before we can specify average pavement brightness or use it for further investigations such as those in this paper, the IES Roadway Lighting Committee ought to define it in a significant manner. The driver requires good visibility all over the roadway at every instant, and until we get an adequate method for computing average brightness we will not be able to evaluate it satisfactorily.

Since the authors had already calculated pavement brightness, obstacle brightness and veiling brightnesses, all of which are essential to the Reid-Chanon method of computing relative visibility, it might be interesting to show a comparison of this method and the contrast method. Fig. A of this discussion shows the contrasts for the medium-angle luminaires in Tables II and IV, and also the Reid-Chanon visibility ratings for these systems. The contrast method shows the 600-lumen system and 20,000-lumen system to be virtually identical, whereas the Reid-Chanon rating seems

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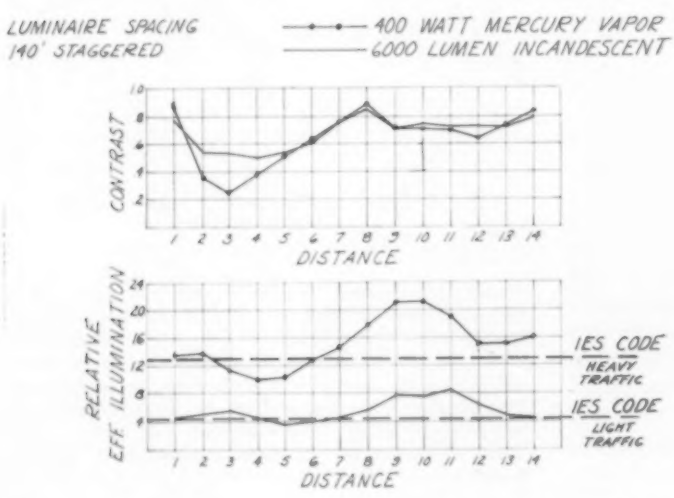

Figure A (Wall discussion).

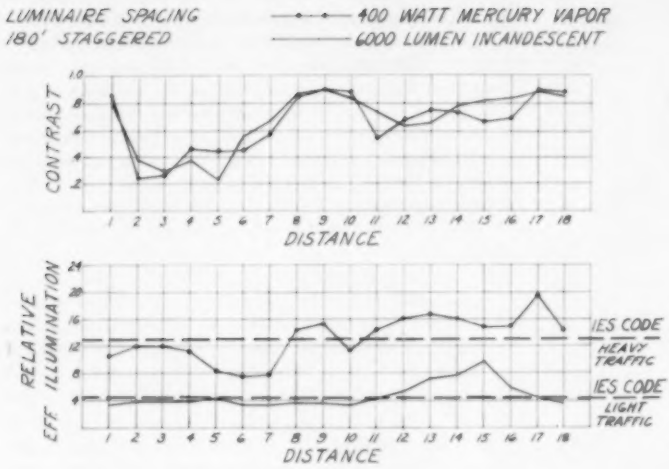

Figure B (Wall discussion).

more sensible. In fact, we can conclude that 6000-lumen lamps probably should never be used on a roadway having more than light traffic as defined by the IES, unless the installation is made with unreasonably short spacings.

Fig. B shows the same kind of comparison with Table III and Table IV.

The authors have presented a most interesting and provocative paper. Works such as this will some day enable us to determine the factors which truly affect seeability and how they may be evaluated and controlled.

M. E. KECK:* I agree with the authors as to their general conclusions and feel that the extensive calculations and the work involved in this paper will help to convince some people that pavement brightness is only one factor in visibility problems, and that it does not possess any outstanding characteristics that make it the best criteria on which to specify and judge a street lighting installation.

I have only one objection to the material presented in this paper; this is in respect to the labeling of the lower curves of Figs. 2, 3, and 4 as "per cent contrast." I feel sure that the authors labeled it in this manner as a matter of convenience and in the full knowledge that contrast, as determined by the formula $C' = B_1 - B_2/B_1 + B_2$ gives a finite number and not a per cent. The reason that I object to the expression "per cent contrast" is that it gives the impression that maximum contrast can be achieved by silhouette seeing. In actuality, contrast by this formula can be either positive or negative.

When the object brightness, B_2 is less than the background brightness B_1, the maximum contrast is limited to unity (object with no brightness and background with any brightness) and increasing the background brightness does not increase contrast. If the object is made lighter, the contrast decreases to zero and if it is made still lighter (object brighter than its background) it increases, and the increase in this case has no limit. Contrast under such lighting techniques can easily exceed the unity. For example, if the authors had chosen a target of 80 per cent reflectance and located it at station 7 of Fig. 2, the brightness of the target would be .8 by E_3, which would be 1.4 footlamberts.

Since pavement brightness and veiling brightness would still be the same, the contrast would be minus 3.25, as computed from the authors' formula. With this contrast figure, the light-colored target would be much more visible than the dark target for which the curve is plotted.

The points which I wish to be considered are these:

(1) Do not assume that the entire range of achievable contrast can be expressed on the lower curves of Figs. 2, 3, and 4 as they are plotted and labeled.

(2) Lighting systems which are evaluated with single reflection factor targets (white discs, black discs, or grey discs) can produce contrasts either all positive, positive or negative, or all negative.

(3) Realistic three-dimensional targets are never simple single reflection factor types and the contrast which produces "first known presence" may be between parts of the target or between any part of the target and its background. The contrast which produces "recognition" and "future position" evaluations by the mind are very complex and can certainly not be expressed in terms of simple single reflection factor targets *vs.* background brightness.

The above comments are not intended as criticism of the authors' material, but are intended to serve as a word of caution to those who may plan to apply the data of this paper to cases which the authors did not anticipate and in areas where the results would be misleading.

C. H. REX:* The significance of this paper is expressed in its final phrase, "designing the lighting system according to the effect that a particular light distribution will have on the ability to see under that system." *Ability to see is the objective* of roadway lighting. This fact is often disregarded in misguided practice. Pavement brightness is one of the principal subfactors in seeing. Brightness of the pavement is a significant visual criterion pertinent to the driver's visual performance. This is well known among knowledgeable highway and illuminating engineers.

Specification, appraisal, and planning of roadway lighting in terms of average pavement brightness is preferable to the use of average footcandles. The application engineers desiring roadway lighting which provides visibility effectiveness in terms of pavement brightness are confronted with the problem of providing average footcandles ranging from *three to five times* higher than the average footlambert result expected.

Fig. C shows how the ratio of average footcandles-per-average footlambert varies for the 17 different roadway

*Westinghouse Electric Corp., Cleveland, Ohio.

*General Electric Co., Hendersonville, N. C.

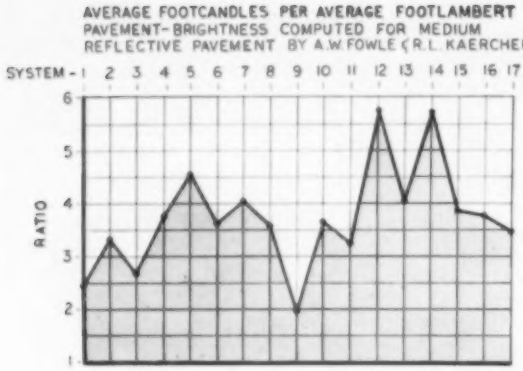

Figure C (Rex discussion).

lighting systems which Messrs. Fowle and Kaercher so thoroughly computed and presented in Table I. To obtain an average pavement brightness of 0.6 footlambert may require average footcandles ranging from less than 1.8 to more than 3.0. This wide variation in footcandle effectiveness must be due to variations in luminaire candlepower distribution and system geometry, including mounting height, spacing, and overhang. The Fowle-Kaercher brightness computations were all based upon the *same pavement reflection data.*

Others have also computed and measured the seeing factor effectiveness of a large number of roadway lighting systems. Computed footcandles-to-produce-footlambert data on eight systems were tabulated during May 1960 for the information of the IES Roadway Lighting Committee. These fc/fL ratios varied from 4.6 to 3.1, depending partially on the basis for computation (average *vs.* average along LRL). Copies of these data are available, along with Mr. J. B. deBoer's suggestion that a fc/fL ratio of 4.0 may be representative for typical United States conditions. The LRL average fc/fL ratio for eight systems is 3.77. The Fowle-Kaercher average fc/fL ratio for 17 systems is 3.79.

Mr. de Boer also provided the Committee with data showing how very favorably their data on pavement brightness produced—per 1000 candlepower from luminaire—compares with that which we derived[1,2] from the Reid-Chanon data.

Messrs. Fowle and Kaercher appear to provide added credence to quotations by others; *i.e.*, "Footcandles are a ridiculously outmoded crutch," and "curing the affliction of the foot and candle disease is long overdue."

The authors also state that a wide range of vertical candlepower distributions are involved in general United States practice. This further complicates the application engineer's job. He must interpolate, mentally estimate, and compromise on the basis of these and other variables to achieve the visibility and visual comfort which he knows the lighting system should provide. The method of achieving more pleasant, attractive and comfortable roadway lighting is quite simple. It involves control of brightness which should be *high* at the pavement level and *low* or *restricted* at the luminaires.

As the authors state, "the application engineer—concerned with the reduction in disability veiling brightness (which also improves the comfort aspect) would have to consider cutoff distributions." We are seriously concerned with the improvement of visibility and visual comfort. Ratings, therefore, should be provided in terms of relative visibility and relative visual comfort. Such ratings, consistent with the requisite visual performance criteria as determined by Blackwell and de Boer[3], should be prescribed by the IES Committee on Roadway Lighting.

Already European countries insisting upon these objectives are adopting codes of practice[3, 4] which specify:

(1) *Visibility* in terms of one of its principal factors—pavement brightness. The brightness specified is appreciably higher than that generally obtained on U. S. highways.

(2) *Visual comfort* in terms of specified *cutoff* or *shielding* of luminaire brightness at vertical angles and distances where luminaires are visible beneath the top of windshields.

Now the United States has the opportunity of assisting international progress by providing the more complete relative visibility and relative visual comfort ratings.[1,2] We should specify:

(1) *Visibility* in terms of the relative visibility of an eight per cent reflectance target, of representative size, and at fixed distance, such as 180 feet in front of the driver.

The scale of numbers for relative visibility may be that of the Finch-University-of-California Visibility Meter, which will soon be available. This instrument includes the wedge which Dr. Blackwell and B. S. Pritchard used in their Visual Task Evaluator. It is currently being manufactured by Karl Freund. This contrast threshold meter has many advantages, including a 30-degree field of view of the roadway including the luminaires which are visible and not cut off by the top of the automobile windshield. It is expected that this one meter will provide an authentic measurement of relative visibility in the 5 to 20 numerical range. Correlations will be developed for computation.

The Luckiesh-Moss Visibility Meter may be used, preferably shielded. Previous measurements and computations have been based upon this instrument and correlations.

The visibility ratings may also be relative-to-requisite[2,5] as measured by the Visual Task Evaluator.

For the measurement of visibility factors, such as the brightness of pavement or obstacle, we have the new Pritchard Telephotometer.[5] Also for actual measurement of DVB (disability veiling brightness), we have the Fry-Pritchard lens attachment for the Pritchard Telephotometer.

(2) *Relative Visual Comfort*, in terms of brightness ratios. These ratings may be computed using a method backed up by extensive measurements[6] using the Guth Evaluator.

Except for the Luckiesh-Moss Meter, the development of these instruments has been sponsored or aided by the IERI. Use of this instrumentation and computer techniques for relative comfort and relative visibility ratings will significantly advance progress during the next few months.

The conversion to seeing factor ratings is taking place. This is timely because a large number of people will be favorably affected. We are all seriously interested in extending the use of *good* roadway lighting to improve night motor vehicle transportation and night living conditions. The traffic engineers and federal, state and county, and city engineers and officials determine *how extensively good* roadway lighting will be installed.

In order that the traffic and highway engineers be encouraged to evaluate the traffic benefit and the general public benefit of roadway lighting, they must have a meaningful, common-sense *base*, such as that provided by relative visibility and relative visual comfort—seeing factor ratings. Without *numerical* ratings the same lighting system may be apraised as "good seeing" or "poor seeing" by two different groups of observers in two different communities. Undefined words for seeing, ranging from excellent to poor, do not provide a suitable basis for the engineering, economic, humanitarian evaluation of benefit on which future progress must be based. Numbers encourage benefit evaluation per units of effective seeing provided. Analysis of benefit evaluations may be used to show how much of the benefit is due to visibility compared with that

due to visual comfort. Availability of such data will help firm-up weighting estimates by which a single *seeing* rating is obtained from numerical ratings for its two principal factors; *i.e.*, relative visibility and relative visual comfort.

The traffic or night transportation benefits of roadway lighting, although obvious, are also susceptible to numerical evaluation.[2] This has been proved by traffic and highway engineers and officials in their evaluation of daytime improvements. Relative visibility and relative visual comfort ratings are urgently required *now*. They are essential to progress.

This paper should include the LRL or at least isocandle candlepower distributions for the luminaires comprising the systems on which the computations are based. This will aid the proper interpretation of the authors' data.

The cutoff, or 65- to 70-degree vertical angle of maximum candlepower distribution, when well proportioned, may increase rather than decrease average pavement brightness, if spacings are reasonable and appropriate.

Tables of constants for pavement brightness at 7 MH (210 feet) distance, obstacle brightness at 6 MH (180 feet) and disability veiling brightness at eye-level out to distances of 15 MH (450 feet) from the luminaire have been widely distributed to Roadway Lighting Committee members and others interested. These constants are available to facilitate computation by others.

We are not surprised that the authors had to go back to 1914 to find someone saying "brightness data cannot be made to replace illumination data."

The authors are congratulated for their contributions and the progress which it represents. We know this work will be continued at a rapid pace.

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J. B. DE BOER:* I should like to express my appreciation for this study. It is such studies, dealing with the problems of pavement luminance, from which we can expect the technique of street and roadway lighting to be lifted from the present stage (in daily practice still primitive) of providing footcandles on the road surface which nobody can see towards the stage at which the road surface luminance and its distribution is a matter of major concern.

The authors quote from the Netherlands Recommendations on Public Lighting an average factor for converting footcandles to footlamberts. I should like to stipulate that it was not the intention to indicate a factor which may be used universally for calculating average luminance values from average illumination values. This will be clear from the last chapter of these Recommendations which contain, for example, results of measurements in some 25 streets showing that even for the small variance in light distribution in the lighting installations considered, the above-mentioned conversion may vary over a range exceeding 3 to 1. Therefore, the average value for this conversion factor has no other meaning but to give a rough idea of the order of magnitude of the road luminance generally to be expected from the average level of illumination, and is not to be considered a reliable value for determining the average luminance in individual cases.

This quotation, as well as the authors' remark that Reid and Chanon's pavement reflectance data are the only complete data available at this time, gave me the impression that the authors are not familiar with the work we carried out in this field. Therefore, I would draw their attention to our studies[1,2] published in 1952 and 1954, which give complete data on four road surfaces in dry as well as wet conditions and, as such, are more complete than Reid and Chanon's data. Our presentation of data allows, moreover, a more accurate computation of road luminances than the one possible with Reid and Chanon's method of presentation. More recently a simple method for giving full information on road surface luminance for a combination of luminaires and road surfaces has been published.[3]

The Road Research Laboratory in Great Britain has also carried out a considerable amount of very fundamental work on the matters of road surface reflection and the computation of luminance.[4,5]

I agree that the luminance pattern of the road surface does not say everything about the quality of public lighting. I like to stress the point, however, that in case glare is limited to a satisfactory degree from the viewpoint of visual comfort, there is not very much more to be concerned about than a sufficiently high and uniform road surface luminance. This is proved by some good European lighting installations for traffic roads using luminaires with light distributions of the cutoff type.

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A. W. FOWLE AND R. L. KAERCHER:* We agree with Mr. Wall's comment that averaging brightnesses in one or more driving lanes cannot give a figure that will fully represent seeability. While the brightness data calculations were based on methods currently accepted in this country, we do not necessarily agree that this represents the entire brightness picture over the roadway as it would appear to a human observer scanning the road surface from one viewing position. Actually, the reflection factor data used represent only the brightness values measured by an instrument pointed to a fixed spot of relatively small dimensions, in a narrow confine, at a given distance ahead of the observer. It is like looking at the roadway surface through a small, narrow tube or telescope which, of course, is not the way an observer sees the roadway area in front of him. It is entirely possible that taking into consideration the apparent brightness values when scanning up and down the roadway at distances other than 210 feet ahead of the observer would furnish different contrast values but, so far, we do not have the correct data on road reflection characteristics available in this country to determine this one way or the

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*Authors.

other. However, extensive studies[1] have been made in this direction in England and it is hoped that further work can be done here.

If variable viewing distances and different driving lanes were used or if it were possible to go even more thoroughly into the subject by integrating the brightness values in the entire field of viewing from each viewing position, in order to obtain a more accurate average background brightness, we would become involved in a fantastic number of measurements and calculations. Because of this the industry has settled on the fixed viewing distance with only the variable of different lateral locations, as used in this paper and as suggested by Reid and Chanon[2] and Rex.[3]

Those who have seen the movie Cinerama will recognize what enlarging the field of view does to one's understanding of what he sees and can realize how the narrow confines represented by a "spot condition" cannot even begin to give us the kind of information that is provided by the whole eye. Some very interesting work along this line has recently been revealed in a paper by J. M. Waldram at the 1960 Association of Public Lighting Engineers' Conference of Great Britain, and reported in the November 1960 issue of *Light and Lighting* (London). This, however, is spilling over into the realm of the psychology of seeing, with which this paper has no intention of dealing.

Mr. Wall has assumed that we have introduced "contrast as a visibility factor." This is not correct. We want to emphasize again, and make it very clear, that the contrast value we computed and discussed was *not* introduced to represent any kind of a measure of effective visibility or visibility distance or to act as a visibility factor. This cannot be done wth a raw contrast value until other faetors are brought into the picture and applied to the contrast data.

This explains the apparently impossible conclusion—that the smaller lamp provided better visibility—mentioned by Mr. Wall. The particular luminaire *distribution* and system design happened in this case to show higher apparent contrast values (which, incidentally, include veiling glare in the calculations and if left out show resultant contrast values to be almost exactly the same). Actually, contrast alone, with or without veiling glare, is no measure of how well the eye sees the object. To determine seeability, the contrast value must be related to the field brightness, adaptation level, object size, motion, exposure time, etc. Other studies by Blackwell,[4] Reid and Chanon,[2] Waldram[5] and Dunbar[6] show that, generally, as the field brightness increases less contrast is required for equal seeing, or equal contrast can provide greater visibility with a higher field brightness. This type of relationship was made by Mr. Wall in his calculation of the Reid-Chanon rating. That is the reason his charts show the 400-watt mercury vapor system to provide a higher rating than the small 6000-lumen incandescent system.

What we are attempting to show is *not* that one unit is better than another from a contrast producing standpoint, but that there is more to the evaluation of roadway lighting systems than a simple appraisal or computation of a single factor, like roadway brightness or horizontal footcandles. The many factors contributing to the ability to see on lighted roadways are so intereonnected that it is necessary to consider them all together, and it is difficult to isolate any one and make it represent the others.

It is helpful that Mr. Keck mentioned that contrast can be either positive or negative, or greater or lesser than unity, depending upon which formula for computing contrast is used and whether the targets are darker or brighter than the general background.

We have no objection to his feeling on the matter of "per cent contrast" and will be willing to accept another label if it will help to give the true impression.

Mr. Keck's points for consideration are excellent. While the range of contrast values can be great or may be based on various kinds of targets— either flat or realistic three-dimensional types—we feel that the low reflection factor target, used herein for purposes of illustration, generally gives a minimum condition of seeability. Larger, three-dimensional or higher reflection types, whether viewed against a pavement background or a lighter or darker surround above the horizon, will generally produce greater contrasts that make the object more easily seen; hence, the low reflection target is safer for general computations.

Mr. Rex has mentioned many factors beyond the intent of this paper. His dissertation is of interest and we are in agreement with his objective of seeing factor ratings.

The amount and quality of visibility, and the measure of resulting information received by the observer, is dependent upon the distribution of brightnesses in the entire visual environment. Since the pavement is a major part of the field of view along the normal line of sight, it follows that pavement brightness, or illumination required to produce it, plays a major part in determining visibility levels as presently computed or measured. This one brightness factor alone, however, does not represent the entire problem. If we boil everything down to the sole criterion of average pavement brightness, are we not guilty of spreading a brightness disease in order to cure the foot and candle one?

The relationship between roadway brightness and incident illumination is much too complex to be represented by a single ratio number. Footcandles and footlamberts are compatible, as pointed out in the paper, because you cannot have one without also having the other. Footlambert brightness is produced by the same incident candlepower that produces footcandle illumination. The way that candlepower is directed to the roadway is what causes the wide variation of resultant brightnesses per illumination shown in Table I and Mr. Rex's Fig. C. Therefore, before pavement brightness can be a meaningful criterion, it should be possible to compute the brightness results for each luminaire light distribution, lamp and system combination the way illumination results are now computed.

This is not impossible to do using computer techniques and standard pavement reflection data. Examples of this have been shown by Mr. J. B. de Boer. These data, however, are not yet readily available to the application engineer or designer. Until such time, we must use the available tools for computing and measuring roadway lighting systems, remembering that brightness results are based not only on the level of illumination but on the way that illumination is distributed over the roadway.

Candlepower data of the LRL or isocandle type as well as plots (similar to Figs. 2, 3 and and 4) of all of the data in Tables II through V, are available to any interested readers.

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INSTALLATION AT SIEBKE AND HOYT CO., 225 2ND AVE. S.E.,
CEDAR RAPIDS, IOWA

Lighting a Jewelry Store

LIGHTING OBJECTIVE: To provide an attractive, inviting environment for display, appraisal and sales in a jewelry store.

GENERAL INFORMATION: Glassware, silverware and jewelry are sold in the portion of Siebke and Hoyt Co. shown in the above photograph and in Fig. 2. This area measures 13 feet between side wall display cases and 48 feet in length. The ceiling height is 10 feet 6 inches. Colors and reflectances of the major store surfaces are:

ceiling	white	80% RF
walls	white	80% RF
floor	tan and white	30% RF
wall cases	brown	10% RF

INSTALLATION: General lighting is provided by two 41-foot fluorescent coves, each equipped with two rows of ten 40-watt T-12 cool white rapid-start lamps in single-lamp channels located as shown in Fig. 2. These coves are located 7 feet above the floor.

Supplementary lighting is provided at counter locations by 16 Gotham catalog No. 573 recessed downlights located as shown in Fig. 2. Each unit is equipped with a 150-watt PAR-38 flood lamp. Units are controlled by switches in the base of each floor case.

Additional general and supplementary lighting is provided by the following: four Holophane catalog No. F1570 units, each equipped with a 300-watt PS-30 incandescent lamp; seven Holophane catalog No. F1560 units, each equipped with a 150-watt A-23 incandescent lamp; and two Swivelier catalog No. 1807 units, each equipped with a 150-watt PAR-38 flood lamp. The location

A.I.A. File No. 31 f

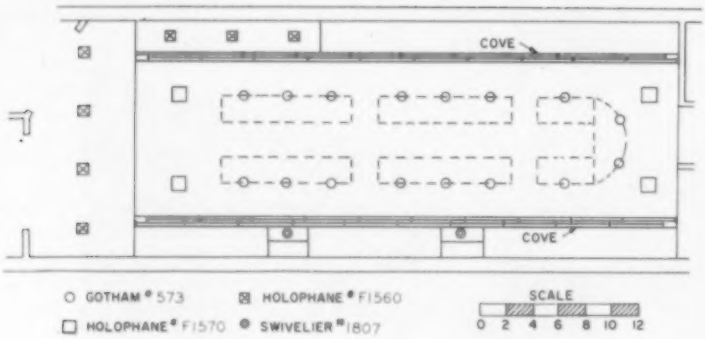

Figure 2. Plan view showing location of lighting equipment.

of these units is also shown in Fig. 2. In addition, the floor cases are equipped with Garey catalog No. 4510 showcase units with 25-watt T-6½ clear lamps on 15-inch centers. The wall cases are equipped with continuous rows of 30-watt T-8 cool white fluorescent lamps in Alzak aluminum reflectors which are recessed in the ceiling of the wall cases.

The average level of general illumination is 30 footcandles in the area shown in the photograph on the preceding page. With supplementary lighting the level of illumination at floor case height varies from 150 to 200 footcandles. The level in the wall cases is 50 footcandles. Brightnesses are: ceiling above cove, 100 fL; ceiling at center of room, 50 fL; wall above cove, 150 fL; outside of cove, 10 fL; and floor, 50 fL.

Lighting designed by J. Charles Young, Iowa Electric Light and Power Co., Cedar Rapids, Iowa.

Lighting data submitted by J. Charles Young as an illustration of good lighting practice and to aid in the design of similar installations.

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The Application of Sodium Lamps to Public Lighting

By J. B. DE BOER

In various western European countries, sodium lamps are considered to be important light sources for traffic lighting applications, primarily for the following reasons: (1) With sodium light one can see better and more quickly and is less troubled by glare than with other light sources. A summary is given of results of investigations in which these advantages of sodium light appear. (2) The application of sodium lamps in place of other light sources makes possible considerable savings in initial and running costs. These economic advantages have gained emphasis from recent developmental work which has led to a considerable increase in the efficiency of sodium lamps (up to 112 lumens per watt) and to the production of higher wattage units. Attention is drawn to a method widely used in the Netherlands for guiding inter-town traffic into and through built-up areas by means of the distinctive color of sodium lighting.

A most noticeable difference between the public lighting in the United States of America and in western Europe is that in many western European countries sodium lamps are used on a very wide scale, while these lamps are hardly used at all in America. In some countries (Great Britain, the Netherlands and Belgium, for example), it can even be stated that sodium lamps are considered to be the most important light sources for traffic lighting applications.

This situation has been brought about, in the first place, by the fact that the human eye sees better and more quickly and is less troubled by glare in sodium light than in the light produced by any of the other light sources commonly employed for road lighting, and in the second place by the circumstance that road lighting can be carried out most economically by the use of sodium lamps.

This latter advantage of the greater economy of sodium light in comparison with other light types in particular has recently been still further accentuated by the important improvements which have been made in the last year or so in the efficiency of sodium lamps. It has even proved possible to exceed considerably the milestone of 100 lumens per watt. Constructional improvements have also been made; the detachable vacuum jacket—which is easily breakable, collects dirt, is difficult to clean and is not always easily handled at the top of a service ladder—has been changed to an integral construction together with the discharge tube, so that the replacement and cleaning of sodium lamps is now no more difficult or time consuming than it is for other light sources which are employed in public lighting.

This new situation, created by these considerable improvements in the sodium lamp itself, makes it of interest to recapitulate the advantages of sodium light with respect to the other types of light for public lighting. This recapitulation is presented in the second section of this paper, and consists mainly of a review of the results of investigations carried out in recent years by the author and his colleagues. In the third section of the paper we have included the results of a number of cost-calculations showing the economical advantages of sodium light for public lighting, in particular for the case of "equivalent" lighting levels. By "equivalent" lighting level we imply the lighting level for various light types whereby the visibility and general brightness impression, etc., are identical. In the last section mention is made of the way in which advantage is taken in many places in the Netherlands of the characteristic color of the light given by sodium lamps, which differs sharply from that of all other light sources used in public lighting. This color is employed to guide through traffic around or through a built-up area towards its further destination.

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Visual Perception Under Sodium and Other Kinds of Light in Public Lighting

A large number of studies on this subject have been made, particularly around the 1930's, but these were carried out mainly indoors. A survey of the most important results obtained up to 1936

has been made by Bouma.[1,2,3] From his own investigations and with the help of observations carried out by other workers (Arndt, König, Luckiesh and Weigel), this author described the favorable properties of sodium light for road lighting with particular respect to perceptibility, limitation of—and recovery time after experiencing—glare and apparent brightness.

It is interesting for various reasons to go further into and to supplement the results of this type of investigation. In the first instance, the many light sources now customarily employed for street lighting, such as the high-pressure mercury fluorescent lamp and the tubular fluorescent lamps were, of course, not included in the earlier investigations. Moreover, most of the experiments were carried out indoors, which makes a confirmation of their results under conditions which closely reproduce the actual situation on the road extremely desirable. Finally, the recent improvements made in sodium lamps have considerably increased the importance of these light sources for public lighting, so that a well-founded documentation of the consequences of the application of this type of light becomes a matter of real importance.

Part of the work carried out by the author and his colleagues (van Heemskerck Veeckens and Burghout among others[4,5,6,7]) was concerned with a comparison of sodium light with other sorts of light, precisely for the above reasons. In view of the unavoidable restrictions on the length of this paper we shall confine ourselves to the description of the most important results of this comparison; thus, to those results carried out on the perceptibility, glare and apparent brightness of the surroundings.

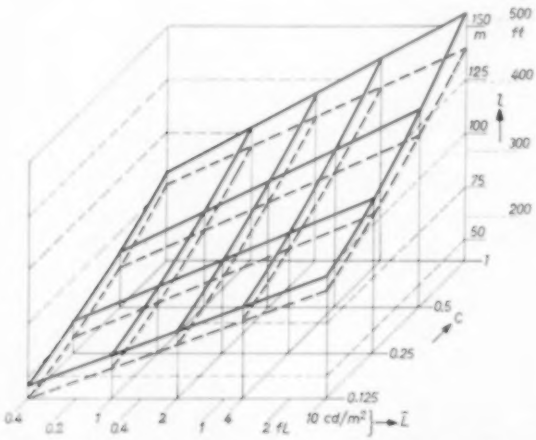

Figure 1. Distance l (in m and feet), calculated from the threshold value measurements in the laboratory, at which the opening in a Landolt ring with a diameter of 160 mm (6.3 inches) can be seen, as function of the background luminance $\bar{L}$ (in cd/m^2 and fL) and the contrast

$$C = (L_{\text{background}} - L_{\text{Landolt ring}}) / L_{\text{background}}$$

Solid lines—with sodium lamp light.
Broken lines—with high-pressure mercury fluorescent lamps.

Comparison of Perceptibility

The experiments carried out on the perceptibility under the various light sources employed Landolt rings. Some of the tests were carried out with a group of 20 observers, indoors, in the measuring set up employed by Balder and Fortuin[8] for their work on threshold values, and followed the procedure worked out by these authors. Other experiments were carried out with a group of eight observers in an open-air laboratory for street lighting, in which a full-sized, faithful copy had been made of a lighted road. Finally, a group of four observers have carried out observations on normal traffic routes. In all of the tests the observers remained stationary. Because of the limited number of observers and the visibility criterion employed (the observation of the orientation of the opening in the Landolt ring), the results of the experiments have only relative value and may not be used for drawing conclusions about the absolute value of the lighting level desirable.

The tests in the open-air laboratory and in normal traffic routes were carried out with Landolt rings with a diameter of 160 mm (ca. 6.3 inches). The indoor tests were made at an observer distance of 6 meters (ca. 20 feet) and, of course, with much smaller Landolt rings. From the threshold value for the ring detail which had to be observed in these latter tests (the average of the results for all 20 observers), a calculation was made of the distance at which the ring opening would have been visible if the ring had had a diameter of 160 mm. The visibility distance l obtained in this way is shown in Fig. 1 as a function of the luminance of the visual field $\bar{L}$ and of the contrast C of the Landolt ring displayed. C is the ratio of the luminance difference between the Landolt ring and the background to the luminance of that background. The solid lines in Fig. 1 give the threshold plane of the visibility distance for sodium light while the broken lines show the corresponding result obtained for high-pressure mercury fluorescent lamps. The tests have also been carried out with the same group of observers for incandescent lamp light. With a background luminance $\bar{L}$ of about 10 cd/m^2 (ca. 3 footlamberts) no significant difference from mercury light was observed. With $\bar{L}$ ca 1 cd/m^2 (ca. 0.3 footlambert), the visibility distances found for incandescent lamp light lay about half way between those for sodium and mercury light.

An analysis of the results of Fig. 1 shows that for equal visibility the average luminance of the road surface under mercury light must be 54 per cent (standard deviation 12 per cent) higher than for sodium light.

Fig. 2 gives the average results of the observations carried out in the open-air laboratory and in normal streets. In this type of measurement, under the practical circumstances of street lighting, a difficulty arises in the form of the lack of the homogeneity in the luminance of the road surface, as a result of which the distance at which the opening in a Landolt ring is just visible varies from place to place. This difficulty was avoided by employing a large number of rings distributed systematically over the road surface (see Fig. 3) and determining the distance at which the orientation of the opening of 80 per cent of the rings could just be perceived.

The results obtained in the open-air laboratory are fitted as closely as possible by two straight lines. An analysis of these results shows that with mercury light the lighting level must be 80 per cent higher (standard deviation 20 per cent) than with sodium light in order to obtain the same visibility distance.

The average results of observations in normal traffic streets show, naturally, a considerably larger spread, since in this case, in contradistinction to

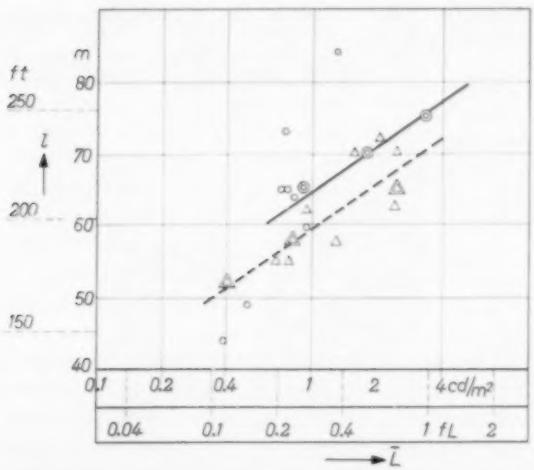

Figure 2. Distance l (in m and feet) at which the opening in a Landolt ring with a diameter of 160 mm (6.3 inches) can be seen, as function of the average luminance of the road surface $\bar{L}$ (in cd/m² and fL), according to measurements carried out in an open-air laboratory and in normally lighted streets.
Circles—with sodium light.
Triangles—with high-pressure mercury fluorescent lamps.
Double circles and triangles—open-air laboratory.
Single circles and triangles—normally lighted streets.

Figure 3. Part of an open-air laboratory for road lighting research, showing movable light masts (mounting height variable between 3 feet and 42 feet). Visibility tests were carried out with, among other things, Landolt rings as test objects. A number of these latter are seen distributed over the road surface.

that in the open-air laboratory, the average road surface luminance is not the only variable; moreover, only half the number of observers were used. If we assume that in normal streets the average road surface luminance influences the visibility distance in the same way as in the open-air laboratory, an indication of the ratio of the lighting levels with mercury light and sodium light required for the same visibility distance can be obtained in spite of the considerable spread of these results. For this purpose one estimates the "center of gravity" of the measuring points obtained in the streets lighted with sodium and with mercury and draws lines through these points parallel to the lines drawn in Fig. 2.

If we do this (we have not shown this in Fig. 2 for the sake of clarity of the diagram), the position of these lines shows that the lighting level for mercury light must be 90 per cent (standard deviation 60 per cent) higher than for sodium light for the same visibility distance.

Glare Comparison

The tests to be described now on the comparison of sodium light with other light sources with respect to the glare experienced with public lighting have been set up with the viewpoint that in the good quality lighting of traffic ways the glare should be so limited that there is hardly any

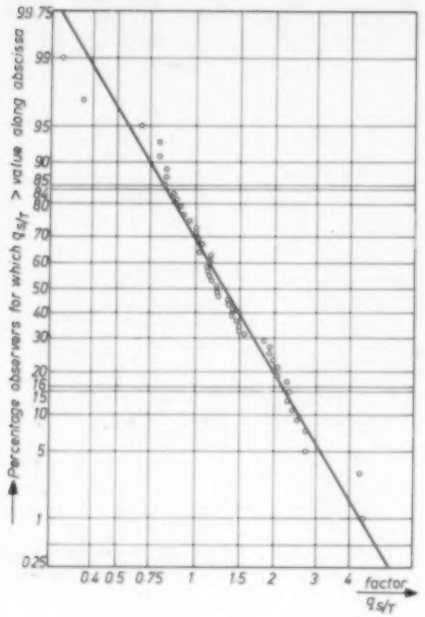

Figure 4a. Percentage of observers finding the ratio $q_{S/T}$ of the just admissible light source luminance under sodium light and the corresponding light source luminance under the light of tubular fluorescent lamps greater than the value plotted along the abscissa.

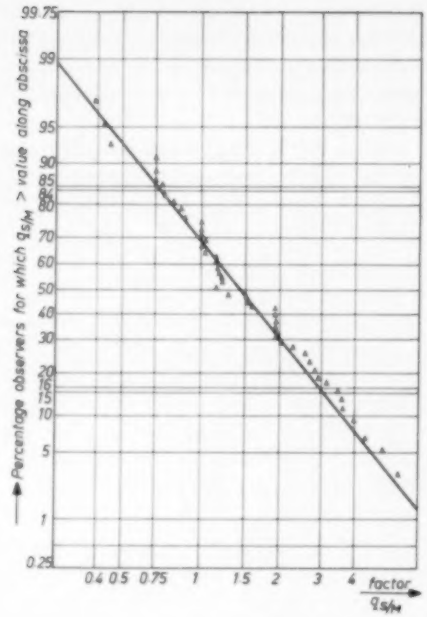

Figure 4b. Percentage of observers finding the ratio $q_{S/M}$ of the just admissible light source luminance under sodium light and the corresponding light source luminance under the light of mercury lamps with fluorescent bulb greater than the value plotted along the abscissa.

question of a deleterious influence on the perceptibility. The so-called disability glare must be negligible. However, even with a hardly noticeable diminution in the perceptibility the glare can cause an appreciable discomfort to the road user and eventually irritate and tire him. In spite of the negligible disability glare, therefore, it is nevertheless possible that so-called discomfort glare can be present.[9] The comparison of the various sorts of light is restricted in the following to this discomfort glare.

Of the experiments carried out in this connection the following are the most important.

1. In a laboratory set up, 50 observers were confronted with a faithful copy of a lighted street, as seen by a normal road user. This street scene can be displayed in various light colors with retention of the same luminance distributon. The observers can vary the ratio of the luminance of the luminaires to that of the road surface. The observers were given the task of adjusting this ratio to the threshold of "just admissible glare."[4] For a constant value of the average road surface luminance, the following ratios were determined for each observer:

$q_{S/T}$ = the ratio of the just admissible light source luminance under sodium light and the corresponding light source luminance under the light of tubular fluorescent lamps with a color temperature of 3000°K.

$q_{S/M}$ = the ratio of the just admissible light source luminance under sodium light and the corresponding light source luminance under the light of mercury lamps with fluorescent bulb.

Figs. 4a and 4b show the results of the observations carried out with an average road surface luminance of 1 cd/m^2 (ca. 0.3 footlambert), set out on probability paper, from which it can be seen that the q-values set out logarithmically display a Gaussian distribution. An analysis of these results is summarized in Table I and shows that with sodium light the luminance of the light sources may be 1.3 times higher than for the light from tubular fluorescent lamps and 1.45 times higher than for the light from high-pressure mercury fluorescent lamps, provided that the average luminance of the road surface is the same in all cases.

The results of these subjective judgments of the

TABLE I.

Ratio	Average Value for 50 Observers	Limits Within Which the Ratio Falls With 95 Per Cent Probability
$q_{S/T}$	1.3	1.1 and 1.5
$q_{S/M}$	1.45	1.2 and 1.8

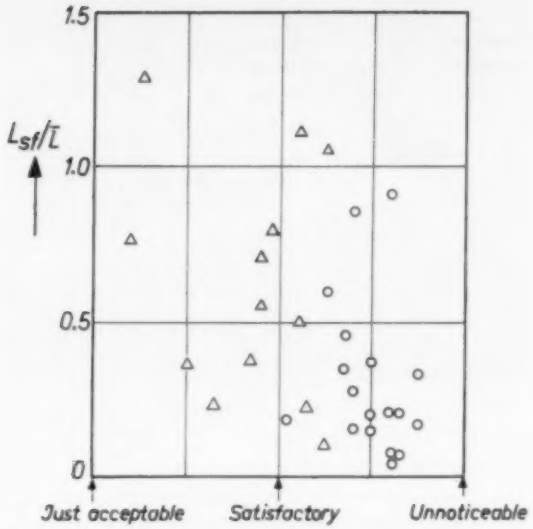

Figure 5. Appraisals of discomfort glare in actual installations.
Circles—with sodium light.
Triangles—with high-pressure mercury fluorescent lamps.

glare from various light sources are in qualitative agreement with those found by Ferguson, Reeves and Stevens,[10,11] who compared sodium light with the light from mercury lamps with clear outer bulbs and from incandescent lamps.

2. In tests in a number of normally lighted streets, a group of 16 observers, mainly lighting engineers responsible for the public lighting of a number of important towns in the Netherlands, have made a subjective evaluation of the glare experienced in these streets. They were requested to express their opinion in the terms: unbearable, distracting, just acceptable, satisfactory or unnoticeable, or with a judgment lying between two successive terms in these series. By giving the numbers 1 to 9 to these levels we were able to determine an average for the evaluations made by these observers. This average is set out in Fig. 5 as function of the ratio $L_{sf}/\overline{L}$ which is calculated according to the results of previous studies.[9]

These results indicate that the average luminance of the road surface L_{sf} in cd/m^2, necessary to reduce the discomfort glare to a satisfactory degree, can be represented approximately by the formula:

$$L_{sf} = \sum_{n=1}^{N} \left\{ \frac{E_n}{7.5\delta_n^{1.3} \cdot \omega_n^{0.4}} \right\}^{3/2}$$

in which N denotes the number of light sources in the field of view; E_n the illumination at the observer's eye, in lux produced by the nth lantern; ω_n the solid angle the nth lantern subtends at the observer's eye in steradians and δ_n the angle, in degrees, between the line connecting the eye with the nth lantern and a plane parallel with the road surface.

TABLE II.

Installation With	Number of Installations in Which the Discomfort Glare Is Considered to be Between:	
	Just Acceptable and Satisfactory	Satisfactory and Unnoticeable
Sodium lamps	0	18
High-pressure mercury fluorescent lamps	7	3

In the above formula the influence of the light color on the comfort experienced due to glare can be taken into account by giving for each of the various colors a different value of the constant in the denominator of the expression in brackets. The value of 7.5 shown represents an average for this constant which can be deduced from the observations carried out in the light from sodium lamps, high-pressure mercury fluorescent lamps, tubular fluorescent lamps (color temperature 3000°K) and incandescent lamps.

If the color of the light were to have no influence on the discomfort glare experienced one would expect that, apart from the spread in the judgment of the glare, the same relationship between the ratio $L_{sf}/\overline{L}$ and the subjective evaluation of the glare caused by the various light colors would be found. That this is not the case can be seen from Fig. 5. It shows that $L_{sf}/\overline{L}<1$ for all sodium installations. The glare in these installations was judged to be between satisfactory and unnoticeable. In 10 out of the 13 installations lighted with improved-color mercury lamps the ratio $L_{sf}/\overline{L}$ is smaller than 1. The glare in these 10 installations is

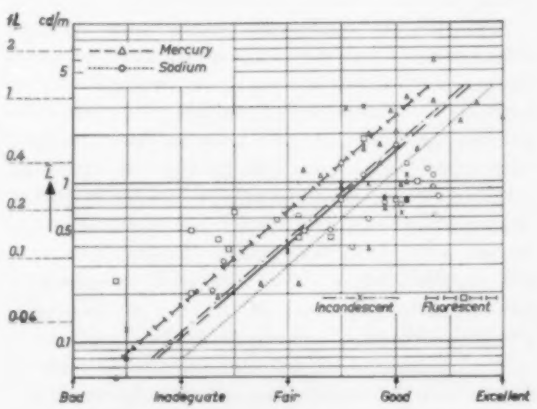

Figure 6. Result of the average subjective evaluation of the road surface brightness plotted against the average road surface luminance $\overline{L}$.

judged to be somewhat less than satisfactory.

According to these results the difference in color between sodium lighting and lighting with improved-color mercury lamps has a significant influence on the appraisal of discomfort glare, as is shown clearly in Table II, which refers only to installations with $L_{sf}/\overline{L}<1$.

Comparison of the Apparent Brightness

The same group of 16 observers mentioned above has made a subjective evaluation of the road surface luminance level in 70 streets. The judgment of brightness level was subdivided as follows: bad, inadequate, fair, good, excellent, or a value between two successive steps in this series. The results of these tests are summarized in Fig. 6, which shows the relationship between the average luminance level $\overline{L}$ of the road surface and the subjective evaluation. Each point in the diagram represented by a circle, triangle, cross or square represents the average evaluation in one street in the code for the light color shown in the diagram. Mercury means the light from high-pressure fluorescent mercury lamps.

A significant relationship proves to exist between the average luminance of the road surface and the subjective evaluation thereof, at least if the results are considered as a whole; thus, not subdivided according to color. This relationship can be approached most closely by the full line in Fig. 6. If the relationship for each color separately were to be approximated as closely as possible by a straight line we should find lines with various slopes. The differences in slope are, however, not significant and the individual results for the separate colors are shown instead in Fig. 6, therefore, as straight lines parallel to the full line and passing through the "center of gravity" of the measuring points for each color separately.

According to these results, the same average subjective evaluation of the road surface luminance is obtained for other sorts of light than sodium light, as for a road lit with sodium lamps when the average luminance of the road surface is raised above that for sodium light by the following percentages: for high-pressure mercury fluorescent lamps, 34 per cent higher; for incandescent lamps, 50 per cent higher; for tubular fluorescent lamps, 125 per cent higher. The standard deviations of these three values are: 21, 28 and 45 per cent, respectively.

With respect to the value of 125 per cent quoted for tubular fluorescent lamps, it must be noted that the installations concerned were the only ones in the whole series equipped with non-cutoff lanterns, while in all other cases cutoff lanterns were employed. It is not unlikely that the high percentage found for tubular fluorescent lamps is thus influenced by the very different glare conditions.

The results of the comparison of sodium lighting with lighting by improved-color mercury lamps show the same trend as that found by Stevens and Ferguson[11] at low-luminance levels.

Summary of Comparisons

The most important results of the various investigations which we have described on the influence of the light color on the perceptibility, on the glare and on the brightness impression of the road user can be summarized as follows:

The comparison of the light of high-pressure mercury fluorescent lamps with that of sodium lamps gives the following results:

a. Both from visibility tests in existing lighting installations and in an open-air laboratory, as from threshold value measurements indoors, it has been found that in order to obtain the same visibility the luminance of the background with improved-color mercury lighting must be at least 1.5 times higher than with sodium light.

b. The luminance of the luminaires in the direction of the eyes of the road user may be almost 1.5 times higher with sodium light than with improved-color mercury light without increase in discomfort glare.

c. For the same impression of road surface brightness for the road user, the road surface luminance with improved-color mercury light must be 4/3 times higher than for sodium light.

The experimental comparison of sodium light with incandescent light and with the light of fluorescent lamps leads to conclusions which agree qualitatively with the three conclusions formulated above, so that they are also in favor of sodium light. The number of observations made in these comparisons is not adequate enough to allow us to draw reliable quantitative conclusions.

The Costs of Public Lighting Employing Sodium Lamps

This subject has become particularly interesting now that the development of sodium lamps during the last few years has led to very considerable improvements in design. As far as the practice of public lighting is concerned, these improvements are important in four aspects:

1. the initial efficiency;
2. the lumen maintenance;
3. the introduction of larger units (higher wattage lamps);
4. the mechanical construction.

As far as the last point is concerned it has proved

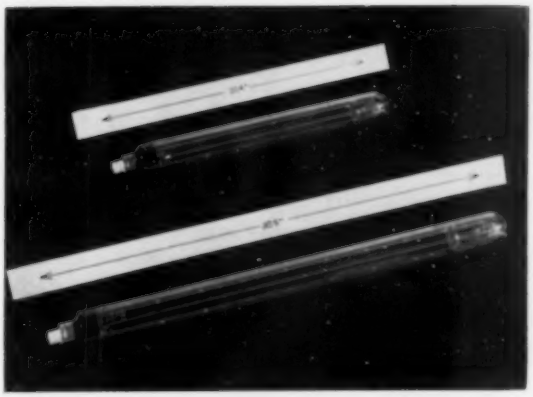

Figure 7. Integral sodium lamps of 200 watt- and 140 watt-ratings. See Table III for most important characteristics.

to be possible and economically justifiable to replace the separate discharge tube and vacuum jacket construction by an integral construction, so that these new sodium lamps now resemble other gas discharge lamps employed for street lighting in this respect. It is interesting to note that this new construction follows very closely one of the earliest constructions employed in the 1930's, abandoned then on cost-price grounds. Newer insight and improved manufacturing techniques have now led us to reverse this judgment.

Secondary advantages of the integral construction are, for example, less maintenance (the detachable vacuum jackets were difficult to clean), less chance of breakage during lamp replacement, and simplification of stocks. Fig. 7 shows the construction and dimensions of these new sodium lamps.

The improvements 1, 2 and 3 mentioned above are illustrated in Table III, which gives a comparison of the characteristics of the classical construction of sodium lamp with detachable vacuum jacket with the newly introduced integral units. With respect to point 3 it will be seen that the lamp series has been extended and now includes a unit of 200 watts.

In order to give an idea of the very much improved economy in street lighting schemes made possible by the new sodium lamp construction, a cost comparison has been made of the lighting of a 36-foot-wide road lighted with high-pressure mercury fluorescent lamps and with sodium lamps. Two different lighting levels have been considered, an average illumination of the road surface of 1 fc and of 2 fc, respectively. Although according to the conclusions drawn from recent investigations on the lighting level this latter must certainly be made higher for routes carrying intense traffic,[7] the values still recommended in many national codes of good practice for such routes lie between the two levels mentioned. For the purpose of this comparison, however, the lighting level has little influence on the ratio of the costs with different light sources for the given level, as will be seen from the calculations which we will now mention.

The data used for these calculations are given in Table IV. The values of the spacing s needed to achieve the lighting levels under consideration have been calculated from the average lumen output of the lamps employed. For this purpose we have used a value of 0.3 for the coefficient of utilization and an average efficiency drop of the luminaires, due to dirt, etc., to 0.75. The prices shown in Table IV represent the average prices presently obtained in three European countries (Belgium, Denmark and the Netherlands).

The results of the calculations are given in Table V. This table gives the initial and running costs of a mile of lighted road both in absolute value (in money) and in percentage. A comparison

TABLE III.

	Classical Construction With Separate Discharge Tube and Vacuum Jacket			Integral Construction		
Lamp Rating	Lumens per watt at 100 hours	Lumens per watt at 4000 hours	Nominal life in hours	Lumens per watt at 100 hours	Lumens per watt at 4000 hours	Nominal life in hours
85 W	72	58	5000	95	85	5000
140 W	76	60	5000	100	90	5000
200 W	....	....	....	112	104	5000

TABLE IV.

Characteristics of the Light Sources Compared			
Light Source	High-Pressure Mercury Fluorescent Lamp		Integral Sodium Lamp
Nominal Watts	400 Watts	700 Watts	200 Watts
Average luminous output (lm)	18,000	32,400	19,750
Average watts (W)	419	732	243
Average life (hrs.)	8000	8000	5000
Prices Which Vary from Case to Case			
Price of lamp ($)	17.00	24.20	14.20
Price of ballast ($)	12.80	18.50	19.80
Price of luminaire for 1 lamp	75.00	95.00	80.00
Price of luminaire for 2 lamps	....	....	125.00
Prices Which Are The Same for All Cases Considered			
Cable price ($)[1]			1.50
Cost of laying cable ($)			1.40
Price of pole ($)			120.00
Cost of the electrical installation from cable to luminaire ($)			40.00
Cost of maintenance per pole per year ($)			8.50
Cost of replacing one lamp ($)			2.00
Cost of one kwh ($)			0.025

[1]In the case of sodium lighting with a level of 1 fc, a cable cost of only $1.2 per foot has been taken because of the low wattage.

TABLE V.

Case	I	II	III	IV	V
Light Type	Mercury	Sodium	Mercury	Sodium	Sodium
Level in footcandles	1	1	2	2	1.5
Spacing in feet	113	124	102	124	165
Number of lamps per pole	1	1	1	2	2
Initial Costs Per Mile					
Cables and switching installation	15,300	13,820	15,300	15,300	15,300
Poles	7480	6810	8270	6810	5120
Luminaires and ballasts	4100	4250	5870	7010	5270
Lamps	795	604	1250	1208	908
Total initial costs in $	27,675	25,484	30,790	30,328	26,598
Total initial costs in per cent	100	95	100	99	86
Running Costs Per Mile Per Year					
Maintenance	396	361	439	361	271
Lamp replacement and cleaning	443	551	686	1102	827
kwh consumption	1960	1033	3792	2069	1552
Total running costs in $	2799	1945	4917	3532	2650
Total running costs in per cent	100	70	100	72	54
Total costs per mile per year in $[1]	5081	4066	7467	6119	4887
Total costs per mile per year in per cent[1]	100	80	100	82	65

[1]Including amortization costs for cables, switching installations and poles (over 20 years) and luminaires and ballasts (over 10 years), both calculated on a rate of interest of 4.5 per cent.

of the costs for the same lighting level, as expressed in the average illumination of the road surface, shows that the new sodium lamps make a considerable saving possible.

The conclusions to be drawn from the tests described in the section of this paper on visual perception show that the comparison of two public lighting installations with different light color but with the same photometric lighting level is a comparison of two installations of entirely different quality, as seen from the standpoint of traffic safety, since this latter is determined by the ease of perception, the degree of glare experienced, etc. Thus, it is reasonable to talk about "equivalent lighting levels" when considering different colors of light. On the basis of the results described in the visual perception section, we would say that a lighting level of 100 with sodium light must be considered to be at least equivalent to a lighting level of 133 with light from high-pressure mercury fluorescent lamps.

For this reason we have included in Table V the lighting costs for sodium light for a lighting level of 1.5 fc, which as far as the quality of the lighting is concerned, can be considered to be at least equivalent to the mercury light installation at 2 fc.

The table shows that, in this latter case, approximately one-third of the total costs per mile per year can be saved if sodium lamps are employed instead of mercury lamps.

Even if American kwh prices, which are often 2 to 2.5 times lower than the European prices, are employed in the calculations, there is still a saving of the order of ¼ of the total costs.

Traffic Guidance by Means of Light Color of Public Lighting

The advantages, described earlier in this paper, of sodium light over other types of light—advantages which are expressed in the first place in better and quicker seeing and in reduced glare and which in the second place lead to considerable economic savings—have been considered in various western European countries to be of such major importance that the disadvantage of unnatural color rendition has been fully accepted. From the standpoint of traffic safety this is, of course, completely justifiable, since the seeing of colors (apart from the colors of visible traffic signals which need their own illumination in traffic at night in order to make them sufficiently noticeable) is of only minor importance for perception in road traffic.

Once such a distinct color as that of sodium lamps, in comparison with that from other light sources used in public lighting, is generally accepted, it is possible to draw remarkable profit from this same light color as a means of guiding through traffic. This principle has now been put into practice in very many places in the Netherlands as a result of the fruitful collaboration between the national and local government authorities together with encouragement from road traffic associations.

It is hardly necessary to state that, because of the advantages mentioned above, sodium light particularly deserves preference where the nature of the traffic makes the best possible traffic lighting essential. Thus, in the "Recommendations on Public Lighting," May 1959, published by the Nederlandse Stichting voor Verlichtingskunde (Netherlands Foundation on Illumination), sodium lamps are exclusively recommended for fast traffic roads outside built-up areas; roads which, because of their traffic density, come into consideration for lighting over either their whole length or locally, for example, at complicated cross-overs. According to the recommendations cited above, this sort of light deserves preference in main thoroughfares and arterial roads inside built-up areas. It is precisely on these types of roads that through traffic is concentrated. On approaching a town only part of the traffic has its end destination there. The remainder of the traffic must be guided as quickly and clearly as possible through, or preferably around, the built-up area which it is not particularly interested in anyway. It is a logical solution, where the fast traffic outside the built-up area has been traveling along roads lighted by sodium, to employ this same light color to lead the traffic to

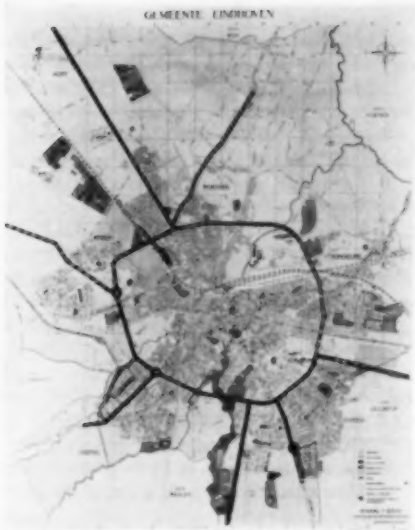

Figure 8. Example of the color piloting of inter-town traffic. The radial entrance and exit roads and the ring road encircling the town center are lighted with sodium vapor lamps (shown in black, solid lines). The other streets are lighted with high-pressure mercury fluorescent lamps or with tubular fluorescent lamps.

the road out of the town, which it must follow to its further destination.

Fig. 8 gives a typical example of this type of lighting planning. It shows the color routing of the traffic in the town of Eindhoven in the Netherlands. The town center is encircled by a ring road which is as yet not quite completed but which, when complete, will have a length of about 15 miles. This ring road and the radiating roads into and out of the town are lighted with sodium vapor lamps and are shown by full black lines (broken lines where the roads are still under construction). Traffic passing Eindhoven is guided along one of the radial spokes to the ring road, follows the sodium light along this latter and selects the desired road leading away from the town, which is also lighted in the same color. This traffic can thus ignore any of the other streets leading into either the ring road or one of the entrance or exit roads, which are lighted by lamps of clearly different color, such as high-pressure improved-color mercury lamps or tubular fluorescent lamps. Particularly that traffic not familiar in a town or district can be given clear guidance in this way, which favors a rapid handling of traffic.

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DISCUSSION

E. G. WENDLING:* Although we disagree with some of Mr. de Boer's conclusions regarding sodium lighting, his comprehensive paper is a good example of the scientific approach to the problem of providing adequate, yet economical, seeing for efficient nighttime transportation.

Mr. de Boer's development of adequate seeing-factor ratings for roadway lighting has resulted in new high-level standards which are being adopted by the Netherlands, are soon to be adopted by Belgium, and are used for guidance by other European countries. These new standards call for higher levels of illumination that should be installed more extensively in the United States. For example, the Netherlands is specifying 0.6 footlambert of pavement brightness or an equivalent average of about 2.5 footcandles under favorable luminaire performance and pavement conditions. Yet, some highway officials are questioning whether this is required and suggest that only one-fourth as much light is needed for comparable or even heavier traffic on United States highways. The adoption by Western European countries of higher illumination levels based upon visibility ratings for roadway lighting is proof that such criteria are essential to similar progress here. We are happy that Mr. de Boer is joining Dr. Blackwell in aiding our IES Roadway Lighting Committee in the development of a more adequate standard practice for North America.

We have the following questions regarding test methods used in the paper. The term "visibility" is used in the reference CIE paper (59.25) by Mr. de Boer and his associates as well as in the Netherlands Standard Recommendations for Public Lighting. In presenting data and opinion surveys on sodium lighting, Mr. de Boer uses the term "perceptibility" instead of "visibility." Why? Why were Landolt rings used rather than solid disc targets? Even though the term perceptibility is used in describing results of tests with Landolt rings, we believe that the tests were

*This discussion is a compilation of comments by Messrs. C. H. Rex, H. A. Breeding and E. G. Wendling, compiled by the latter. All are with the General Electric Co., Hendersonville, N. C.

a static determination of visual acuity or visual discrimination. These questions lead to the fundamental consideration of whether visual acuity or visual perception should be the criterion for determining the adequacy of the street lighting system.

No mention was made in this paper of consideration being given the dynamics of the driving situation, since all tests were made with stationary observers and targets. Recognizing the work that Mr. de Boer has done in this area, we would be interested in knowing whether correlation has been established between these test results and the "dynamics of seeing."

We would also like to know if Mr. de Boer has correlations available comparing the visibility distance of the orientation of the opening in the Landolt ring *vs.* fixed distance relative visibility ratings for targets being used in United States studies, such as plain black discs (12-inch diameter), small black dogs, or mannequins with 20 per cent reflectance.

Mr. de Boer seems to imply that tests made in the 1930's regarding the effects of color of light upon visibility may not have been conclusive on the grounds that they were indoor tests. By the same token, a major portion of the test evidence in his paper is based upon indoor tests with a 20-foot observer-to-target distance. We would like to know what differences in test procedure from those described in the Reid-Chanon paper[1] could be said to validate Mr. de Boer's conclusions.

Mr. de Boer's use of a number of Landolt rings at varying observer-target distances in outdoor tests as a visibility or perceptibility criteria circumvents the need for a visibility meter. However, the variation of distance, which changes the size of the visual task, has been found to be undesirable by Dr. Blackwell. Assuming that Mr. de Boer's observer-task criteria can be shown to be representative, we would like his opinion of using a single Landolt ring target observed at fixed distances such as 200 feet with the aid of a threshold visibility meter.

We have the following comments regarding factors which this paper may have assumed or omitted, including those which may be dissimilar between European and North American conditions.

Although photometric details of test luminaires used were not included in the paper, we note that sodium, mercury and incandescent units were of the cutoff type while fluorescent units were of the non-cutoff type. This important difference begs the question of whether test results are completely valid even from a qualitative standpoint. It is our conviction that even the variance in degree of cutoff and shielding of the sodium, mercury, and incandescent luminaires could have much influence upon appraisals of comparative perceptibility, glare, and pavement brightness.

The effects of color upon speed of visual assimilation are not considered in this paper. In a sense, this contradicts the approach wherein Landolt rings were used as a measure of visual acuity, rather than perceptibility. Certainly the color of objects is of vital importance in determining visual discrimination, particularly under dynamic conditions. With sodium or any other monochromatic light, we know that color discrimination is impossible except by highly trained observers.

We are further interested in test conclusions which Mr. de Boer may have reached regarding the effect upon driver alertness and fatigue after driving for long periods of time under monochromatic lighting.

The esthetics of outdoor lighting, we believe, are not fully considered. Of course, this is almost entirely a subjective evaluation and thus Mr. de Boer's statement that, "In Western European countries the disadvantage of unnatural color rendition has been fully accepted," may be true of certain European countries. Fortunately, or unfortunately, we are convinced the opposite situation exists in the United States. Based upon previous experience with sodium lighting, there is a great deal of negative reaction, both from the general public and lighting engineers, against the unnatural color qualities of sodium lighting.

If sodium lighting is felt to have all of these advantages in Europe, we wonder why it is not used for all classes of city streets and highways rather than primarily for traffic lighting applications. If the answer is that broad usage would negate the color routing or delineation benefits, we then wonder whether the real advantage of sodium lighting is not the delineation effects rather than the improved visibility, reduced glare, and higher pavement brightness. If the nature of sodium lighting is such that it is useful only for purposes of delineation, it causes us to suggest that there are equally effective means of accomplishing this objective. Yellow mercury lamps are used to some extent in the United States for this purpose and, for that matter, so are yellow fluorescent lamps or yellow enclosing plastic globes. It is agreed that in the case of yellow mercury and fluorescent lamps this is accomplished at the expense of lamp efficiency; however, even greater economic advantage is gained in the use of identical luminaires for the complete lighting system. Since economy of installation, operation, and maintenance is important also in Europe, we would expect that standardization of luminaire types would be of similar advantage to European users.

Perhaps the most serious obstacle facing the use of sodium lighting here is that it works against the efforts of the industry and the acceptance of the public for lighting of better *color quality* as well as greater quantity of illumination. In this respect the promotion of sodium lighting by the industry can only be considered a backward step to progress. This is, of course, a consideration that is nonscientific in every sense, but that is, nonetheless, of vital importance. It may be claimed that past practices of the lighting industry have, in some respects, ignored the desires and needs of the general public. Some have claimed that we have at times forgotten the fundamental fact that all funds for lighting come directly or indirectly from the individual taxpayer. To design lighting systems for lighting engineers while ignoring public preferences can in the long run be fatal to the industry. We believe this fundamental fact is just beginning to gain recognition in the United States. If, as we believe, the public wants lighting of better quality (including color) we must be prepared to provide it if progress is to be made. Although there are certain undeniable advantages to sodium lamps, they fail badly in the important aspect of providing desirable color qualities.

One of the basic premises of this paper, in urging consideration for sodium lighting, is "that road lighting can be carried out most economically by the use of sodium lamps." Although there are significant differences between European and American practices in the design and installation of roadway lighting, we have reviewed the economic analysis on the basis that such variables be minimized for easier comparison. To that extent we have assumed identical conditions with the exception that United States equipment performance ratings and prices were used.

The two most significant differences are:

(1) The fact that luminaire utilization efficiency of 30 per cent, used in the paper for both mercury and sodium luminaires, seems reasonable for a sodium luminaire design

but is much too low for United States mercury luminaires. American units of high quality design provide from 20 to 25 per cent higher utilization efficiency.

(2) The values for useful lamp life. This paper used 8000 hours while United States values are 50 per cent greater, or 12,000 hours.

By factoring in only these major differences we conclude that the total cost of a sodium system is about five per cent higher than our mercury systems on an equal footcandle basis. If, as Mr. Reid's discussion points out, we use conditions of application more typical of American practice, the economic advantage of mercury lighting is increased to 15 to 20 per cent over sodium lighting. *If* we assume that 1.5 footcandles of sodium are equivalent to 2.0 footcandles of mercury, we find that sodium has a cost advantage of less than nine per cent, using United States values of performance and price, rather than the 35 per cent advantage arrived at in Mr. de Boer's paper. From this we conclude that, in the United States, there is no significant economic advantage in favor of sodium *vs.* mercury, based upon presently available sodium lamps and the present state of the art in sodium luminaire design.

1. Reid, Kirk M., and Chanon, H. J.: "Evaluation of Street Lighting." *Transactions of the Illuminating Engineering Society*, Vol. XXXIV, No. 10 (December 1939).

JOHN W. YOUNG:* The work on applied roadway lighting carried out by Mr. de Boer and his associates should influence further development and trials of the sodium light source by others; *e.g.*, in evaluating visibility in relation to other types of sources and, furthermore, in the cost of sodium illumination with differing lighting system geometry and luminaire optical designs.

The sodium source cannot be ignored as an effective light source in public-way lighting. Though sodium lighting in the United States has never advanced to the stage of its acceptance and use abroad, the low brightness characteristic of the lamp and its luminaire are well known, as is the increased visual acuity in the case of sodium as a monochromatic light source. Thus, the observer notes that there is an apparent ability to discern objects on the roadway more quickly and that the contrast of objects is sharper and more vivid.

The advantage of better visibility of sodium in comparison with other sources has been reported in recent years as possibly in the order of 15 per cent. Undoubtedly, some who have carried out researches on visibility of objects under different color illuminants may challenge the defined advantages shown by the author's findings. Among the conclusions, for instance, is that for the same visibility the luminance or brightness of the background must be 1.5 times higher for the improved-color mercury source than for sodium light.

This margin in favor of sodium is substantial over what has been considered favorable in the past. The observer does not fail to notice, however, the enhanced contrasts produced by sodium. Furthermore, in monochromatic light, there is no question of chromatic aberration, which has been recorded as "another reason for the clarity of vision in sodium light." A personal note as an observer might be added. Under sodium lighting of quality (high level, excellent luminance properties, sharply controlled glare), there resulted a sensation of clarity in seeing not heretofore experienced. But, just to confound the experience, excellent visibility prevailed upon entering a mercury lighted street, of virtually the same high quality, directly from a sodium section.

A natural reaction in considering sodium is a desire for a fuller scientific understanding of the complex function of color of light and seeing. Although they do not understand, physiologically, how color is associated with the visual process of the eye, people are becoming more conscious of outdoor illumination, and the psychological factor of the sodium color is important. Surveys abroad disclose reactions running from preference for sodium by vehicle drivers to others who dislike the color violently. To this observer, the impression of the distinctive color has always worn off after riding under such color for only a few minutes.

The new sodium linear lamp, at 100 lumens per watt, must be respected among the sources suitable for roadway lighting, for its potential economy if nothing more. A unique feature is that the color may serve as a roadway delineator to guide traffic over selected streets, such as through-routes or by-pass streets in communities. In addition, rural intersections lighted with sodium inform the driver of an intersection or important traffic interchange ahead and are illuminated by the same source that indicates warning or attention.

This paper offers for evaluation pertinent material on lighting public ways. A possible comparison of lighting practice in the United States with the costs in Table V and the "equivalent lighting levels" may be mentioned briefly. It is that recent improvements in mercury lamps point to one lamp to two sodium lamps over the same service interval (assumed 10,000 hours). This, together with some higher utilization of generated light (at good shielding of the luminaire) than used in the Table indicates that, per footcandle, the sodium would have slight advantage, if any. More complete comments are intended in time.

We appreciate this contribution by Mr. de Boer on the outstanding developments in the sodium lamp and its application. This source appears to be well established in some countries and its fortunes as a roadway lighting source well be followed with increasing interest.

KIRK M. REID:* The topic of sodium roadway lighting is of particular interest because we have been wondering why sodium roadway lighting has such widespread and apparently growing use in some European countries, in contrast with limited and diminishing use in this country. This contrast in practice has raised two broad questions in the minds of many of us: (1) Are there some basic differences in the evaluations made in this country and abroad of sodium roadway lighting as compared with other sources and practices? (2) Are there some substantial differences in the economics, in this country and abroad, of sodium roadway lighting compared with other sources and practices? Thanks to Mr. de Boer, we can now answer both questions—in the affirmative. Yes, there *are* important differences in the evaluations, and in the economics.

It may be noted that the Reid-Chanon studies[1,2] of visibility on lighted roadways as affected by color of light are not mentioned in Mr. de Boer's paper nor included in the references he cites. In brief review, the studies Mr. Chanon and I made employed both a one-eighth scale test model highway, shown in Fig. A, and actual roadway lighting installations. Our facilities in the test model highway enabled us to measure roadway visibility with sodium, mercury, and incandescent lamps *having the same light output*

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Figure A. One-eighth scale test model highway used in the Reid-Chanon studies on visibility of roadway obstacles as affected by color of light.

and distribution from each source. Our only variable was color of light. The findings as reported in our paper are as follows:

"Seven observers making approximately two thousand observations found that equal visibility was obtained with four per cent less light from the incandescent lamps than from the sodium-vapor. The average of the mean variations for the individual observers was seven per cent.

"A further test was made, with objects on the beam beyond the second lamp, in which the observers were required to distinguish between an angular and bifurcated 'man' and a rectangular obstacle of the same general proportions. The purpose was to ascertain what part acuity plays in the recognition of such obstacles. Seven observers, making approximately fifteen hundred observations with an average mean variation of six per cent, found equal visibility with three per cent less light from the incandescent than from the sodium-vapor lamps. This result is particularly interesting because it shows no practical difference in the visibility afforded by the two illuminants at threshold levels, even where the task is the exacting one of discriminating between two obstacles of similar general dimensions. This would indicate that the one quality of light does not enable one to see an obstacle sooner or farther away than does the other."[1]

The problems in comfort evaluations of roadway lighting systems, particularly where there are differences in color of light, are not new. In 1936 P. J. Bouma of Philips attempted such evaluations.[3] In his paper, Mr. Bouma commented, "In general the blue rays are mainly responsible for the discomfort produced. Hence yellow light results in less discomfort than white light." Later in the paper he concludes, "The observers were also asked whether they found the sodium light or the white light more discomforting. About 25 per cent expressed no opinion, whilst of the remainder 66 per cent suggested the sodium light was the more trying and 34 per cent the white light." Faced with this contradiction between theory and observations, Mr. Bouma finished with the cautious statement, "The experiments just described indicate that measurements based on a small number of observers can be employed only with the greatest reserve for arriving at any conclusions."

Now that such authorities as Messrs. de Boer and Bouma have broken the ice in appraisals of discomfort as affected by color of light on lighted roadways, I make bold to report an unpublished portion of the 1936 Reid-Chanon observations on the test model highway. We asked a large number of observers—my recollection is at least 50—whether they found any significant difference in comfort between the three lighting systems, sodium, mercury and incandescent, having the *same amounts of light similarly distributed*. About three-quarters of the observers reported no significant difference in comfort. Of the remainder, about half picked the sodium as more uncomfortable and half picked the mercury. The incandescent lighting, rightly or wrongly, escaped criticism. Were these results significant? Well, we did not think so at the time.

As further studies are carried out, here and abroad, it is reasonable to expect that the present differences in evaluations and judgments will be narrowed if not eliminated. That is the course of progress.

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2. Reid, Kirk M. and Chanon, H. J.: "Determination of Visibility on Lighted Highways," *Transactions of the Illuminating Engineering Society*, Vol XXXII, p. 187 (February 1937).
3. Bouma, P. J.: "The Problem of Glare in Highway Lighting," *Philips' Technical Review* 1, nr. 8, p. 225 (1936).

D. A. TOENJES:* Mr. de Boer has presented a thorough analysis of the high-efficiency sodium lamp for roadway lighting. We are indebted to him for including discussion and information concerning the several factors that contribute to the choice of a lamp type for a given set of lighting requirements.

In the section of the paper where the author describes the use of Landolt rings for the comparisons of perceptibility, he points out that the results have only relative value and may not be used for drawing conclusions about the absolute value of the desirable lighting level. Further on, however, he asserts that a lighting level of 1.5 footcandles with sodium light can be considered to be at least equivalent to a mercury installation of 2.0 footcandles. At this point it would appear that the author, despite his earlier precaution, has indeed applied his results to some absolute values.

The author comes to certain conclusions as to a necessary 54 per cent increase in average luminance of the road surface under improved-color mercury light, as compared with sodium light. According to Fig. 1, this percentage difference in luminance would vary as a function of both road luminance and contrast. For what specific set of conditions is the author's 54 per cent figure intended to apply? If it is to be interpreted simply as a representative figure, does it apply to the average of existing roadway lighting installations, or to installations which conform to recommended practice?

It would be helpful if the paper had included candlepower distribution curves or data on the street lighting luminaires that were compared in the various systems. Otherwise we have no direct way to determine the variation in pavement illumination and brightness, which limits the acceptable spacing. It also appears that the discomfort-glare comparisons (and perhaps those of subjective brightness) are really comparisons of different street lighting *systems* rather than of different colors of light.

As to use of the yellow color to mark certain traffic routes, we are in full agreement with the author. To a small extent, this technique has already been used in this country with our yellow mercury lamps. These lamps, al-

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though much lower in efficiency than the sodium lamps, have an advantage in their color rendition, as in distinguishing the color of red stop signs. However, the chief application of the yellow mercury lamps has been for "caution" lighting at railroad grade crossings and at heavy-traffic highway intersections.

The author indicates that the color of light is not so serious a consideration as to forbid the use of sodium lamps, even for general street lighting use. We cannot agree for street lighting applications in this country; we would consider the yellow light from sodium lamps as acceptable only for highways, where pedestrians need not be considered. Furthermore, we are inclined to wonder just how literally we are to accept the author's dismissal of color as a factor of any consequence in roadway lighting, when we note that the mercury lamps he uses in his comparisons are of the improved-color design, instead of clear. Surely the clear mercury lamps could give more precise optical control from street lighting luminaires, and a higher coefficient of utilization, than the phosphor-coated lamps.

It may be of interest to compare Mr. de Boer's summary of lighting costs, with both mercury and sodium lamps, with similar figures for conditions that we believe to be representative for this country. Because of the color of sodium light, we are confining the comparison to highway lighting only. The mercury lamps used in our comparisons are of the clear 400-watt design, for the reasons mentioned above. Color of light is not so important in highway lighting, and the candlepower distribution patterns may be relatively narrow. Under these conditions we generally find the clear mercury lamps to offer visibility with greater lighting economy than phoshor-coated mercury, incandescent, or fluorescent lamps. In this instance, we have made the basic comparison upon an average maintained illumination level of 0.8 footcandle. It should be noted that we differ from Mr. de Boer (as outlined in Dr. Guth's comments) in our premise that the sodium lamps should not be assigned any advantage in "rated visibility for equal illumination" as compared with other colors of light.

We have assumed the roadway to be a divided highway, with a 30-foot pavement width on each side, and a 50-foot divider strip. The lighting units are mounted at a 30-foot height, in a one-side arrangement on the right-hand side of each half of the divided highway. They overhang the curb by a distance of 5 feet. Power is supplied by directly-buried underground multiple circuits. The energy rate is 1.5 cents per kwh. Other estimated costs and operating conditions are shown in Table A.

About a year and a half ago, our calculations indicated that sodium lighting for highways in this country would be even less economical, as compared with clear mercury lamps. Those results were based upon the 80-lpw efficiencies then achieved in European sodium lamp designs with the U-shaped arc tubes. But the newer lamp designs offer a more compact size (thus improving the luminaire's candlepower distribution pattern) and greater wattage than the former 140-watt design, as well as higher efficiency. As expected, therefore, its lighting economies have been improved over those with the former lamp design, becoming more nearly comparable with the clear mercury lamp for this application.

We now estimate that the luminaire with the newer sodium lamp would have about 26 per cent coefficient of utilization, based upon our best interpretation of data for similar luminaires, and the mounting height and pavement width described above. For a luminaire using the clear mercury lamp (instead of a phosphor-coated lamp as in the author's comparison), the coefficient of utilization is 41 per cent under the same conditions. Based upon these figures, and our estimates of sodium lamp prices in this country, our calculations lead us to expect such a sodium-lamp system to be from 10 to 15 per cent more costly than an equivalent mercury lamp system.

TABLE A—Estimated Costs and Operating Characteristics

Mercury Lamp Characteristics (H33-ICD Lamp)
Initial light output—19,500 lumens (in horizontal operation)
Approximate mean lumens—95 per cent of initial
Maintenance factor—lamp, 91 per cent; luminaire, 85 per cent; combined, 77 per cent
Mortality—17 per cent burnouts at 8200 hours; assume that lamps are group replaced at 8200 hours (2 years) of operation
List Price—$20.00
Sodium Lamp Characteristics
Initial light output—22,400 lumens
Approximate mean lumens—20,800 lumens at 4000 hours
Maintenance factor—lamp, 93 per cent; luminaire, 85 per cent; combined, 79 per cent
Mortality—estimated 15 per cent burnouts at 5000 hours; assume that lamps are group replaced at 5000 hours
Estimated list price in U. S.—$33.00
System Operating Costs and Characteristics
Mechanical breakage of lamps—0.10 lamp per luminaire per year (from handling, accidents, and vandalism)
Energy costs—1.5 cents per kwh
Truck-and-time charge
$5.00 for each burnout replacement
85 cents (per unit) for group cleaning and relamping
Cost of lamp inspection (group relamping practice)—4 cents per lamp
Burning hours per year—4100 hours
Power Losses in System
Network transformers—13 watts per kva of load
Losses in secondary conductor—33 watts per kva of load
Estimated Equipment Cost, Per Luminaire
Network transformer—$30.00 per kva
Underground conductor (directly buried, no ducts)—$3.00 per foot
Control—photoelectric type, included in luminaire price
Estimated Installation Cost, Per Luminaire
Network transformer—$2.00 per kva
Underground conductor—$2.00 per foot
Pole and luminaire—equal to 100 per cent of equipment cost

In order to evaluate the effect of a possibly higher coefficient of utilization, we have also calculated the results with an assumed 35 per cent coefficient for the sodium-lamp luminaire, even though it may be unrealistically high. With this coefficient, the sodium-lamp system would deliver equal illumination with the same pole spacing as the mercury-lamp system. In that hypothetical case, we find that the total cost per mile would be almost identical for the two lighting systems in this country, although under European conditions the author has shown the sodium-lamp system to cost about 20 per cent less than mercury.

In conclusion, the relative cost-of-light comparisons would appear to be significantly different for conditions in this country as compared with those in Europe, as shown by Table B. As noted before, the sodium lamps are not assigned any advantage in relative visibility for equal illumination. Briefly, let us mention some of the economic factors that account for such a difference.

Installation costs for a United States highway lighting system are assumed to be over twice as great as for a rather similar European system, while the original equipment itself appears to be quite similar in cost. The pole

TABLE B—Summary of Comparative Lighting Costs

	Mercury	Sodium	
		Based on general assumptions	Assuming higher C.U.; listing only the affected values
Basic Data			
Initial lamp lumens	19,500	22,400	
Rated lamp life, hours	12,000	7,500	
Average lamp watts	400	200	
Approximate watts loss in ballast	50	43	
Watts per luminaire (with ballast, transformer and line losses)	471	254	
Coefficient of utilization (C.U.)	41%	26%	(35%)
Maintenance factor—lamp only (per cent of initial)	91	93	
Maintenance factor—luminaires only (per cent)	85	85	
Maintenance factor—combined (per cent)	77	79	
Luminaire spacing, feet	255	190	(255)
Average maintained illumination, footcandles	0.8	0.8	(0.8)
Approximate net lamp price (60 per cent of list price)	$12.00	$19.80	
Owning Cost Per Luminaire			
Net cost of luminaire and ballast	$115.00	$140.00	
Net cost of pole and bracket arm	$118.50	$118.50	
Net cost of transformers, conductors and control	$779.10	$532.60	($772.60)
Estimated installation cost	$744.40	$609.00	($769.00)
Total initial cost	$1757.00	$1400.10	($1800.10)
Annual owning cost (12.5 per cent of initial cost)	$219.60	$175.00	($225.00)
Operating Costs Per Luminaire			
Lamps replaced per year, group relamping	0.50	0.82	
Lamps replaced per year, spot relamping (burnouts and breakage)	0.185	0.223	
Annual cost of replacement lamps	$6.00	$16.24	
Annual cost of lamp inspection for group relamping survivors	$0.02	$0.03	
Truck and time cost for group cleaning and relamping	$0.42	$0.70	
Truck and time cost for spot relamping	$0.92	$1.12	
Annual energy cost	$28.95	$15.62	
Total annual operating cost	$36.30	$33.70	($33.70)
Total Costs Per Luminaire or Mile			
Total annual owning and operating cost, each	$255.90	$208.70	($258.90)
Luminaires per mile of dual roadway	41	56	(41)
Annual cost per mile	$10,490.00	$11,700.00	($10,610.00)
Relative annual cost per mile	100%	112%	(101%)

spacings determine the number of poles and luminaires needed under the various systems, and in turn are determined by the coefficients of utilization already described, for equal illumination within acceptable limits of uniformity.

It appears likely that the ratio of the sodium lamp's price to that of the mercury lamp would probably be about twice as great here as is indicated for European conditions, due chiefly to the relative costs of the methods of manufacture for the two lamps; but changes in this ratio have only a relatively small effect upon the total cost comparison. Truck-and-time costs for system maintenance here are assumed to be about 2½ times as much as in Europe. Furthermore, our calculations are based upon greater differences in average life between the mercury and the sodium lamps. Energy rates are here estimated as 1.5 cents per kwh, as compared to 2.5 cents in the paper. As the author has already mentioned, a lower rate would reduce the relative advantage of the sodium lamp.

SYLVESTER K. GUTH:* Mr. de Boer has presented impressive evidence which appears to favor sodium lamps. However, a number of questions arise regarding his choice of criterion for evaluating visual ability and certain conclusions derived from his experimental results. Futhermore, his studies on normal streets and in the open-air laboratory appear to involve comparisons of lighting systems rather than solely the spectral quality of light emitted by the various lamps.

Most practical roadway seeing situations do not involve the discrimination of fine detail. On the contrary, the objects which must be seen usually are relatively large, but of low contrast. Mr. de Boer did introduce the factor of contrast in his studies of visual acuity. However, according to our calculations, the visual angles subtended by the break in the 160-mm diameter Landolt rings ranged from 2.75 to 0.70 minutes of arc for his observation distances. For this range of visual angles—representing discrimination of small detail—he finds that a sodium source is superior to a mercury source. This agrees with results reported by Luckiesh and Moss[1] for sodium and tungsten-filament lamps in an acuity test. These authors found no significant difference between mercury and tungsten-filament lamps, which also agrees with Mr. de Boer's results.

Using a different type of criterion—the time required for threshold seeing—Luckiesh and Moss[1] found a definite superiority of sodium over tungsten-filament light for a *small high-contrast* test object (Fig. B). On the other hand, when Luckiesh and Moss used a *large low-contrast* test object they found no significant difference between these two illuminants. Since objects on roadways usually are relatively large but of low contrast, the conclusion has been reached in this country that acuity tests are pertinent only to a limited extent in evaluations of visual ability on lighted roadways. Hence, in most practical roadway seeing situations, color of light plays a minor role. Futhermore, because of the fact that sodium light has a marked effect upon the appearance of colored objects, it may even reduce contrasts.

As a matter of interest, Mr. de Boer's relationship between contrast and luminance for mercury light has been compared with Blackwell's data[2] for tungsten filament light. The comparison of these sources is permissible because most investigators have found relatively small visual differences between them. The curves shown in Fig. C are for test objects which subtend visual angles of 1.3 minutes of arc. It is assumed that the author's data are for 100 per cent accuracy of the Landolt rings seen and an indefinite exposure time of the test object. Blackwell's data are for 99 per cent accuracy and a one-second exposure time. One major difference is that the de Boer criterion was discrimination of the break in the Landolt ring and Blackwell's was the detection of the presence of a circular luminous spot. Such differences in experimental procedures make comparisons of absolute values difficult. Nevertheless, one would expect the form of the curves to be similar, just as the form of the Blackwell curve is similar to those obtained by other investigators. It seems to me that the de Boer contrast-luminance relationship should have a similar form unless uncontrolled and extraneous factors have influenced his results.

Regarding the threshold levels, the Blackwell technique achieved lower values than those found by other investigators for corresponding experimental conditions. Considering all factors, including experimental differences, it is difficult to understand why the de Boer curve falls below

*General Electric Co., Nela Park, Cleveland, Ohio.

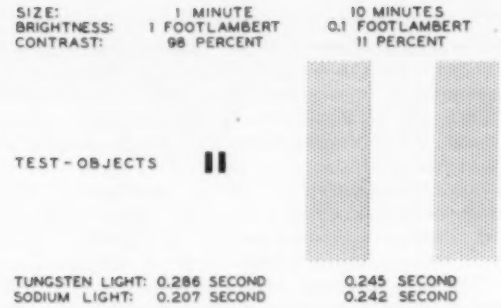

Figure B (above). The minimum time required to recognize a small high-contrast and a large low-contrast test object with sodium and tungsten filament light.

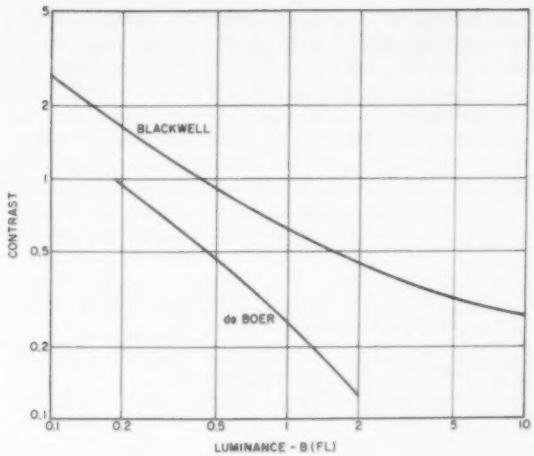

Figure C (right). Difference in shape of contrast-luminance thresholds as found by de Boer and by Blackwell.

the Blackwell curve. The threshold curve for discrimination of detail is characteristically higher, not lower, than that for the detection of presence.

It is difficult to reconcile Mr. de Boer's conclusions with the data shown in Fig. 2 for the open-air laboratory and the actual streets. The straight lines approximately fit the laboratory data but not the observations on actual streets. A redrawing of Fig. 2 is shown in Fig. D. The best fit lines have been determined by the method of least squares. The results with high pressure mercury fluorescent lamps in normally lighted streets (single triangles, dashed line) approximate those obtained in the open air laboratory. However, the sodium lighting on normal streets (single circles, dashed line) does not agree with any of the other experimental conditions, being considerably steeper. It would seem that something markedly different in the viewing conditions of the normally lighted streets with sodium lamps has influenced the visual abilities of the observers.

No information is given regarding the contrast of the Landolt rings used for obtaining the data shown in Fig. 2. Furthermore, the visual sizes of test objects represented in Fig. 2 and the corresponding roadway brightnesses do not seem to bear any definite relationship to the data of Fig. 1. Therefore, one can only conclude that factors other than spectral quality of light are influencing the results.

This brings up what may be an important difference among Mr. de Boer's indoor laboratory, outdoor laboratory and normal street experimental situations. The last two involve different luminaires for sodium, mercury, tungsten-filament and fluorescent lamps. No mention is made of the similarity or differences in the luminaires used in the indoor laboratory tests. The observations obviously can be influenced by many factors other than the spectral quality of light. These other factors, such as light output, distribution from different kinds of luminaires, and different patterns of pavement luminance, cannot be ignored because in many cases they will have greater significance than the color of light.

It is presumed that the experimental conditions used for obtaining Figs. 4a and 4b involved identical sizes of luminaires for all light sources. If not, this could have an important effect on the judgment of glare. Were all portions of the photographic reproduction of the street scene spectrally nonselective in reflectance?

The ratings of sodium and mercury lighting presented in Fig. 5 in all probability include evaluations of the types of luminaires used for these two sources, plus other factors such as luminance distribution on the roadway and surrounding areas. What would the results have been for *identical* systems except for the color of light?

The ratio $L_{sr}/\overline{L}$ can be considered a discomfort glare rating. Only three mercury systems had ratings greater than unity; all other such systems fell within the range of ratings for the sodium systems. It seems strange that even those mercury systems with the lowest ratios were not considered at least as good as the sodium systems with the highest ratios. In other words, just what were the observers evaluating?

The comparisons of apparent brightness (Fig. 6) are subject to question because of the selective reflectance of many surfaces on or adjacent to roadways (red brick, green grass, etc.). Even eliminating the roadway as a factor, the luminance of surroundings, due to selective spectral reflectance and different distributions of light from the luminaires, could be considerably higher or lower for some sources

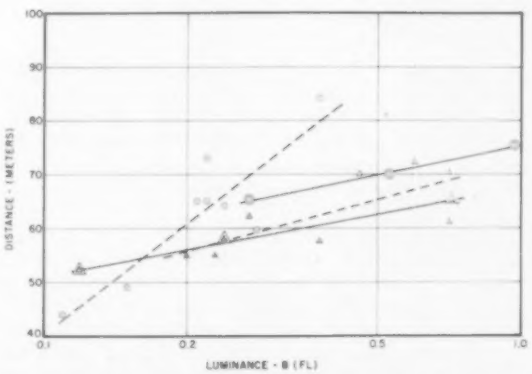

Figure D. A replotting of de Boer's relationship (Fig. 2) between the distance in meters at which the break in a Landolt ring can be seen and the average luminance of the road surface for normally lighted streets and the open-air laboratory.
Circles—with sodium lamps.
Triangles — with high pressure mercury fluorescent lamps.
Single circles and triangles—normally lighted streets.
Double circles and triangles—open-air laboratory.

than for others. It is obvious that the luminance of surroundings will have a considerable influence upon the apparent brightness of a roadway. Such effects have been pointed out by Luckiesh and Moss.[3]

In summary, most of Mr. de Boer's conclusions favoring sodium light do not seem to be substantiated by a consideration of some of the practical aspects of seeing on lighted roadways. The sodium lighting systems he has evaluated may be better than those involving other sources, but this should not be attributed solely to the spectral quality of the light.

1. Luckiesh, M. and Moss, F. K.: "Seeing in Tungsten, Mercury and Sodium Lights," *Transactions of the Illuminating Engineering Society*, Vol. XXXI, p. 655 (July 1936).
2. Blackwell, H. R.: "Development and Use of a Quantitative Method for Specification of Interior Illumination," ILLUMINATING ENGINEERING, Vol. LIV, p. 317 (June 1959).
3. Luckiesh, M. and Moss, F. K.: "Seeing in Sodium-Vapor Lights," *Journal of the Optical Society of America*, Vol. 24, p. 5, 1934.

R. N. THAYER:* Table III shows an increase in 100-hour lumens per watt from 72 to 76 for separable-jacket designs, to 95 to 100 for the same sizes in integral construction. This is about a 30 per cent gain, yet it is our understanding that the change to integral-jacket design provides only a 10 to 15 per cent gain. Will the author please indicate what other design improvements have contributed to the total gain which he reports.

Along the same line, the figures shown in Table III indicate that 4000-hour lumens per watt have increased from 80 per cent to 90 per cent of the 100-hour value for the changed jacket design. We would not expect that this change, largely a mechanical one, would influence per cent maintenance. Aren't other design improvements also included here?

In Table IV, the Netherlands price of the 200-watt sodium lamp is shown to be less than either the 400-watt or the 700-watt mercury lamp. We estimate that this relationship would probably not hold true in the United States because of the relatively higher labor content in the production of sodium lamps.

E. G. WOTTON:** Mr. de Boer's paper gives me the opportunity of raising a matter which has puzzled me for some time. My reading shows that the sodium lamp was introduced to the North American market in the mid-1930's. At present, the lamp is not listed in the manufacturers' catalogs. Would the author care to hazard a reason for the disuse of the lamp?

The author may be interested that a considerable number of sodium lamps are in use in Canada. They enjoy a vogue as a source for floodlighting and are also used in some street lighting installations. They are used in particular as warning lights at busy street intersections and railway crossings. Their solid yellow color is much more effective for this than the anemic yellow of the yellow mercury lamp.

The lamp life of 5000 hours quoted by the author is, from my experience, conservative. Would Mr. de Boer please explain how he arrived at the figure? Does his method of assessment differ from that commonly used in North America? Incidentally, neither the text nor the tables refer to either the 280-watt or the three-foot linear sodium lamps.

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**Amalgamated Electric Corp. Ltd., Toronto, Ont.

Mr. de Boer does not mention luminaire design. The sodium lamp is a most convenient one for the designer to work with. On the one hand the lamp is not so long and cumbersome as the fluorescent tubes used in street lighting. On the other hand, the designer does not worry about a concentration of heat experienced with mercury lamps. As a result, luminaires for sodium lamps are simply and inexpensively made from light but durable acrylic plastic. Early designs were based on the use of drape formed acrylic sheet with refractors machined from the same material. Presently, the injection moulding technique is widely used.

With a 140-watt or 200-watt sodium lamp in a luminaire with a medium angle beam, we would expect to get a peak intensity of perhaps 3000 to 4000 candelas. This compares with 10,000 candelas or more currently obtained with some 400-watt mercury luminaires. Would the author care to comment on this disparity and give his views on the need to limit the peak intensity?

J. B. DE BOER:* The very detailed discussion of various points in my paper has strengthened my conviction that the question as to how far sodium lamps must be regarded as potentially important light sources for traffic lighting in this country is worth the lively interest of your Society. I am grateful to all those who have contributed to this discussion and for the opportunity they have thereby given me to clarify my standpoint on various issues. The following comments are in answer to Mr. Wendling.

By *visibility*, I mean that an object can be seen under very well-defined conditions, while *perceptibility* in road traffic implies the much more complicated phenomenon of seeing, localization and recognition, etc., of an object.

The tests described had as their purpose the comparison of the power of observation with various colors of light. The most desirable method for this is undoubtedly that which we followed in the determination of the desirable lighting level for traffic lighting, by the determination of the distance at which observers can see objects of, for example, *ca.*, six-by-six inches from a moving automobile.[1] In view of the enormous spread in the results of such observations a very large number of observations must be carried out. We have therefore sought a less expensive method of testing which can nevertheless produce relatively valuable results.

Landolt rings are particularly suitable for the collection of a large quantity of easily checked observation material. For traffic lighting it is most important to know the visibility of an object at a distance of *ca.*, 100 metres (300 feet). With reasonably good quality street lighting, Landolt rings of the approximate size used by us are needed at this distance to get the opening in the ring on the border of visible-nonvisible. The question arises at once as to whether the detail which is then in use as a criterion for visibility is not so small that only the question of "visual acuity" is being investigated.

We can answer this question as follows:

(1) It is not possible to measure "visual acuity" in itself. An object can be seen, as appears from Fig. 1 for example, since the combination of size of detail, luminance contrast and time of observation is more favorable at the given luminance of the visual field than in the threshold situation. In Fig. 1 the time of observation, which was 0.8 second, was omitted.

(2) The test object of six-by-six-inches at the distance of 300 feet can certainly not be considered as unimportant

*Author.

for traffic safety as far as size is concerned. This object is seen under an angle of ca., 6 minutes of arc. It can be shown experimentally that the decrease in the size of the object from 6 minutes of arc to 0.5 to 3 minutes of arc (the area investigated in our tests, see Fig. 1) has hardly any influence on the relationship of the threshold situation between the two colors of light on which Fig. 1 is based. It can thus be assumed that the conclusions drawn from Figs. 1 and 2 also apply for an object, important from the traffic safety point of view, of six-by-six-inches at a 300-foot distance.

(3) In contradiction to the opinions which are usually held with respect to the type of object of importance for observations in road traffic, it must be concluded that the possibility of observing small details contributes to a considerable extent to the convenience with which one can see on the road and thus to the comfort of the road traffic. A lighting installation for which it is questionable whether a pedestrian or a dog can be seen at 300 feet is in my opinion not worth discussing. What is important is, for example, if I can see at a glance, just as in daylight, if a pedestrian standing at the side of the road is looking at me, or if I can see a glimpse of an automobile moving in front of the truck which is immediately in front of me, or if I register immediately, even subconsciously, small sideward deviations of the automobile approaching me in oncoming traffic. It is these details which determine whether or not I must consider the pedestrian as a potential danger, or whether or not I commence an overtaking maneuver. That the so-called contrast sensitivity (once again, a concept which in itself does not exist) should be determinant for observation in road traffic, may be of importance to a certain extent for the primitive observation possibilities in which we are unfortunately placed by most road lighting installations today. It is certain, nevertheless, that only when details such as those mentioned above, much smaller than an object of six-by-six-inches at a distance of 300 feet, can easily be observed, is seeing comfort being achieved which is comparable with that of seeing on the road during the day.

The tests described have a comparative character, so that a correlation between static and dynamic tests has not been sought. An impression of such a correlation is possible, if only approximate, because of the limited number of observations and observers in the dynamic tests, by comparing the two types of tests.[1]

The correlation between the results with Landolt rings and plane disc targets can be derived from a comparison with the results published by the author at the CIE Congress in 1951. Here again care must be taken in connection with the different teams of observers.

We, as well as Reid and Chanon and others, have carried out indoor tests. The reason for this is evident—variation of one of the factors which one wishes to study, keeping all the others constant, is much easier in a model test. We have, nevertheless, been extremely careful not to report the results of any indoor tests when they could not be confirmed qualitatively by the results of outdoor tests. When the results of indoor and outdoor tests have led quantitatively to different results, in drawing our conclusions we have always employed those results which displayed the effect observed to the smallest extent, thus leading to a cautious formulation of the conclusions.

The experience which we have gained in the past with various types of visibility meters, in connection with the investigations we carried out in preparation for the CIE Congress in 1951 at Stockholm, has made us somewhat skeptical as regards the value of these instruments in general. As was already shown by A. Waller,[2] it is possible to make an instrument which gives a clear measure of the visibility with the surroundings of the object kept constant by reducing the visibility conditions to the threshold conditions by variation of one of the quantities determining the visibility (detail, contrast or time of observation). Of these possibilities, the second—reduction of the contrast—is employed in the Visual Task Evaluator used by Dr. Blackwell and others.

In order to be able to work with these instruments with sufficient accuracy, however, considerable experience is necessary. For this reason the number of observers who can cooperate in the tests is very small, which is a very limiting circumstance for the majority of the problems under consideration. Furthermore, in none of the visibility meters described up to the present is the visual field really equal to that of the direct observer.

The observation of the Landolt ring via a visibility meter is of little value. The shape of the Landolt ring is intended to give the test leader a means of checking (via the correct recognition of the orientation of the opening in the ring) whether or not the threshold situation has been correctly determined. With this method of checking there is no need for a visibility meter in which the continuously visible object is brought by the observer into the threshold situation by a measurable change in one of the factors determining the visibility.

Differences in light distribution of the luminance with light sources of different colors of light were present only in the tests relating to the single circles and triangles, Fig. 5 and Fig. 6.

The glare produced by the luminaires in the installations to which the circles and triangles in Fig. 2 refer is so small that even a complete shielding of these fittings by means of a screen at a short distance in front of the eyes of the observer does not markedly influence the visibility distance. Since for both types of light sources investigated only installations with diffusing luminaires without an accompanying optical system have been investigated, the differences in light distribution are small, as are those of the situation of the luminaires with respect to the road surface. There is no question of a systematic influence on the visibility distance.

The differences in light and brightness distributions of the luminaires employed in the tests of Fig. 5 are discounted in the ratio $L_{vt}/\overline{L}$, as can be seen from the formula for L_{vt}.

In the results of Fig. 6 a noticeable influence of the light distribution of the luminaires is only to be expected if the results of the fluorescent lamps—which have not been taken into consideration in the conclusions—are compared with the others.

Mr. Wendling's opinion differs from the results of the recordings made by Mr. Waldram in Great Britain of the reactions of observers in traffic, both in daylight and by artificial light, which show that it is only very seldom that the color of the detail in the visual field determines whether or not it is observed. On the basis of these tests, which I have been able to follow closely, and on the basis of a close study of what one see daily in traffic, I am inclined to replace Mr. Wendling's words "vital importance" by "minor importance."

I have not been able to observe any greater degree of lack of driver alertness or tiredness on roads lighted with sodium light than on roads lighted with other colors of light. The fact that even tests on the influence of the light

color on tiredness organized systematically in the laboratories did not give reproducible results leads one to expect that such an influence under the very variable circumstances on the road is also not to be expected.

As far as esthetics are concerned, sodium lighting is certainly not to be recommnded for those streets where good color rendition is important (shopping streets, streets and squares with a predominantly representative character and with a lot of pedestrian traffic, etc.). Where the interests of motorized traffic predominate, experience in various European countries has shown that the shortcomings in color rendition are accepted. It is surprising, moreover, that the friendly aspect of many villages which are lighted entirely with sodium is preserved. If the need for normalization in the field of street lighting in America is, indeed, felt so strongly, as would appear from Mr. Wendling's comment, I would suggest that the uneconomical high-wattage incandescent lamp and the unsuitable (for street lighting) fluorescent lamp—particularly with respect to the control of the light contribution—should be replaced by either fluorescent mercury or by sodium lamps wherever, for example, 10,000 lumens or more per lamp are necessary.

In answer to Mr. Wendling's statement that United States luminaires of "high quality design" provide from 20 to 25 per cent higher utilization efficiency than that of the sodium luminaires, I fear that Mr. Wendling's attitude to "high quality design" for road lighting differs considerably from mine. Lighting a road properly implies, more than the concentration of as much light as possible on the road surface. Not only the road surface, but also the verges at the side of the road and any buildings close by, serve as a background against which objects on the road must be seen.

Although undoubtedly a higher utilization factor can be achieved for luminaires for non-improved-color high pressure mercury lamps than by the use of these lamps with fluorescent coating or of sodium lamps, I do not consider this to be in any sense advantageous. On the contrary, that part of the light which in the two latter cases falls at the side of the road because of the lower degree of light control is the very minimum that is necessary for the lighting of the immediate surroundings of the road, and must thus be considered an advantage rather than a disadvantage for the lighting installation as a whole. Furthermore, since the utilization factor of luminaires for fluorescent mercury differs only slightly from that for sodium lamps, the assumption of the same utilization coefficient for both types of luminaires is justifiable.

The remarks of Mr. Young on the economics of sodium lamps can best be dealt with together with those of Mr. Toenjes on this same subject.

I appreciate Mr. Reid's contribution to the discussion, particularly in view of his reputation in Europe for his extensive and fundamental research, in collaboration with Mr. Chanon, in the field of street lighting. Mr. Reid reproaches me with justification, for not having referred to his investigation into light color, and I hasten to offer him my excuses. I can find no explanation for the differences in the results of our investigations. The results referred to by Mr. Reid do not seem to me to be valid for the comparison of sodium light with mercury light, improved-color or not. The differences in visibility which I found were not only determined in three different series of investigations of entirely different character, but also by other investigators, more recently by Dr. Jainski.[3]

With regard to the differences in visual comfort with various colors of light, I have only mentioned the most striking results in my paper. In addition to the results I have reported here, we have found similar results in a totally different series of investigations which were, moreover, later confirmed in an investigation with 30 observers, results of which have not been published.[4] In this latter investigation a method of judging was followed, derived from the work of Ferguson, Reeves and Stevens which, incidentally, also provides a qualitative confirmation of our results.[5,6]

Summarizing my answer to Mr. Reid's comments, I consider that all these results provide a sufficiently firm basis for the conclusions which I have formulated.

I would like to remind Mr. Toenjes that when I state that one United States dollar is equivalent to 3.8 Dutch guilders, my remark is only relative and I am not implying anything as to the absolute purchasing power of either of these monetary units.

The 54 per cent deduced from the results, given in Fig. 1, is valid as an average for the region investigated and, thus, for the range of luminance found in normal street lighting installations.

As is already evident from the commentary on the discussion by Mr. Wendling and his associates, the differences observed are indeed to be ascribed to the light color, since possible differences in systems were either negligible in their influence on the effects investigated or have been allowed for.

Mr. Toenjes' remarks on the acceptance of color have already been dealt with. His question as to why improved-color mercury lamps are used instead of non-corrected lamps on many European roads can best be answered by the following:

(1) *Traffic roads*—Color rendition unimportant, thus sodium lamps or, if need be, clear mercury lamps, if these latter were not so uneconomical.

(2) *Squares, streets with pedestrian traffic, etc.*—Reasonably good color rendition desirable; thus, fluorescent mercury or fluorescent lamps of higher efficiency.

(3) *Interiors*—High requirements on color rendition; thus, fluorescent lamps with good rendition or incandescent lamps.

Mr. Toenjes' remarks on the economy of the various types of lamps appear, on further examination and in contradiction to his own conclusions, to confirm my own conclusion that even under American conditions sodium lamps can make possible considerable savings. From my remarks in answer to Mr. Wendling, it will be seen that it is only worth while comparing luminaires with the same coefficient of utilization. If the value of 0.35 employed by Mr. Toenjes is inserted for both types of light sources, and the price relationship chosen by him for lamp, ballast and luminaire, which are based only on estimates, are corrected by the figures we have based on production experience, then the sodium lamp installation proves to have 10 per cent lower annual costs than the mercury installations of *the same illumination level*. This is not very different for the value of 20-per cent found by us for this case, particularly when one takes note of the much higher amortization used by Mr. Toenjes for the cables and transformers. This amortization accounts for a much larger portion of the total costs than assumed by us, and minimizes possible differences, since it is not dependent upon the color of the light. I can understand Mr. Toenjes' point of view when, without much or any traffic experience in good sodium lighting installations or participation in investigations into the influence of the light on visual observations, he does not immediately accept the fact that the lighting level with sodium only

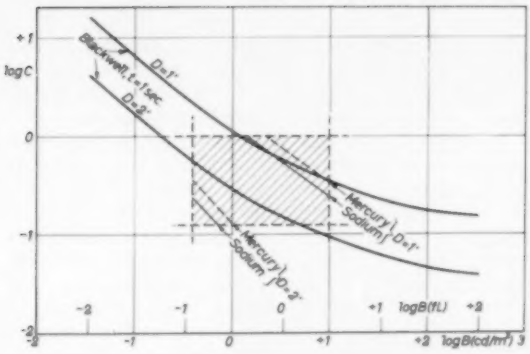

Figure E. Comparison of the results from Fig. 1 (straight lines within rectangle) with those of Blackwell (IE, p. 327, Fig. 8, June, 1959; 50 per cent accuracy).

needs to be three-quarters of that with mercury. In this respect I would suggest that he and Dr. Guth, to whom he refers, set up two comparable installations of a reasonable size with sodium and with mercury and then continue the discussion after having gained experience with these installations.

Dr. Guth also fears that, in some of our investigations, differences in systems and not those in light color are responsible for the results we have found. I have rebutted this opinion above, but am rather disappointed to hear this opinion from Dr. Guth, who has had the opportunity to convince himself of the facts *in situ*.

It will be clear from this that I do not share Dr. Guth's opinions on the importance of the observation of large or small details on a lighted road. I cannot help feeling that Dr. Guth, in considering that "the objects which must be seen are usually relatively large," has based his opinion too much on what can be seen in streets which are lighted to what is, unfortunately, the customary standard, instead of what one should be able to see.

The data given in Fig. 1 are for 50 per cent accuracy and an exposure time of 0.8 second. Fig. E shows the positions of the lines which appear in Fig. 1 by taking sections through the vertical planes corresponding to $D = 1'$ and $D = 2'$ (corresponding to $l = 110$ m and $l = 55$ m) in comparison with Blackwell's data for 50 per cent accuracy and 1 second exposure time. The differences in position are easily explained from the enormous influence of the age of the observers and the individual spread among observers. Fig. F gives an impression of this for the region under consideration, this figure being based on unpublished results of Balder and Fortuin.[7] Not only the position, but also the slope of the curves, differs considerably for the various age groups (as also from individual to individual, which is not shown in Fig. F). With the results shown in Fig. F in mind, the position of our results in Fig. 1 compared with those of Blackwell is not surprising. Here again, it must be remembered that it was not our aim to achieve absolute results. Only of importance for our conclusions is how the results found for the various colors lie with respect to each other. Since we always worked in comparable situations, with the same team of observers, this aim was achieved.

Dr. Guth has noted in his Fig. D and associated text in *extenso* what I have said more briefly in my paper; *i.e.*, the very high standard deviation (60 per cent) of the stated difference of 90 per cent. Since all installations investigated have identical luminaires (simple luminaires without any optical system, in which the lamp is screened to 10 degrees below the horizontal), the spread in the results can only have been due (apart from a small number of observers) to differences in locating the luminaires with respect to the road surface and the Landolt rings. However, when one restricts oneself to the determination of a general average of the results found in normal streets, as we have done, the results obtained under much better controlled circumstances in the indoor and outdoor laboratory are confirmed. No more than this is intended with the reporting of the results in normal streets and our conclusions are based exclusively on the results obtained in the laboratory.

Dr. Guth has apparently only a vague recollection of that which I showed and told him about our test installations during his visit. In correction of his remarks on the supposed difference in luminaires, etc., in our indoor and outdoor laboratory tests, I can assure him once again that all comparisons with different colors in these tests related to installations which were otherwise completely identical. For example, in case actual luminaires were used, then luminaires of equal dimensions and light distributions at the same mounting height, spacing and overhang above the same road surface and in the same surroundings were similarly employed.

Since Dr. Guth has carried out observations himself in the set-up with which, among other things, the results of Figs. 4a and 4b were obtained,[4] I think that he must know that we have indeed worked with identical dimensions of the light sources and that no measurable influence of possible selective reflection of the photographic reproduction employed here need be feared.

I am further surprised about the doubt expressed by Dr. Guth on the value of the interpretation of the results given in Fig. 5 which also, insofar as the 10 mercury and 18 sodium installations under consideration are concerned, have reference to luminaires of the above mentioned simple type. The method followed here is not fundamentally different from that which Dr. Guth himself recommends as chairman of the CIE Expert Committee dealing with the problems of discomfort glare.

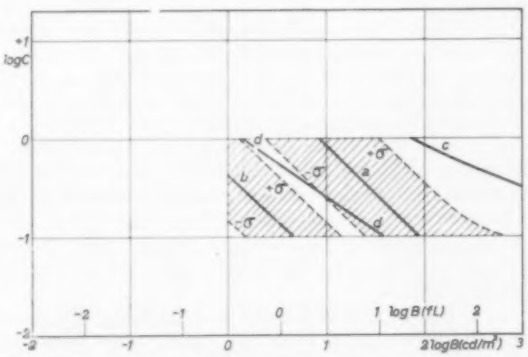

Figure F. Threshold measurements for various age groups. $t = 0.8$ second. Light from incandescent lamps. D = size of detail in minutes of arc.
a **= average results at $D = 1'$ and observers' ages between 15 and 24 years.**
b **= average results at $D = 2'$ and observers' ages between 15 and 24 years.**
c **= average results at $D = 1'$ and observers' ages between 55 and 64 years.**
d **= average results at $D = 2'$ and observers' ages between 55 and 64 years.**

The possible influence of selective reflection of the road surface and surroundings on the results of Fig. 6 is, so far as the photometric luminance of the visual field is concerned, included of course in the values set out along the ordinate of this figure. Of the various factors other than light colors which determine the apparent luminance, moreover, this particular factor is in my opinion one of the least important for street lighting. Further, in view of the large number of streets involved in this investigation and, as far as general characteristics are concerned, the similar nature of these streets, it is difficult for me to believe that all the other influential factors should just be precisely favorable for the judgment of the apparent luminance of sodium-lighted streets.

For these reasons I consider Dr. Guth's summary of his commentary as unjustified. I repeat the suggestion I made in answer to Mr. Toenjes because, to use Dr. Guth's own words, "his conclusions will be substantiated by a consideration of some of the practical aspects of seeing on lighted roadways."

Mr. Thayer's question regarding the gain in efficiency achieved in changing from separable jacket to integral-jacket design could properly serve as an introduction to a paper on the extraordinary improvements made in this lamp type in recent years. I think it just possible that Mr. Thayer is thinking of the 10 to 15 per cent gain obtained on changing from the separate-jacket construction to the simple single-walled integral vacuum jacket construction. The 30 per cent gain over the separable jacket has been largely achieved by fitting an extra thermally-insulating glass-sleeve over the arc-tube inside the integral vacuum jacket and redimensioning the lamp where necessary.

The improvement in lumen maintenance is due to an improved method of presenting sodium migration to the coldest part of the arc tube during life, whereby certain parts of the tube are ultimately starved of sodium vapor, with a consequent drop in light output. By preventing or greatly minimizing this, the lumen maintenance is improved accordingly. This feature cannot be employed in separable jacket types because of the risk of damaging, during insertion, the protuberances on the arc tube which are employed to prevent this migration.

Mr. Thayer's final point can best be answered by the fact that the price relationship between the sodium and mercury lamps I used, which was based of course on European production conditions, is valid for approximately the same degree of mechanization for both types. Furthermore, I understand that, so far as can be seen at present, further mechanization possibilities do not differ appreciably for the two types. Under these circumstances, I consider that the price relationship I have employed is a reliable figure for reasonable manufacturing quantities of both types, any difference in labor costs affecting the lamp prices to roughly the same extent.

As a European, I do not feel very competent to answer Mr. Wotton's question as to why sodium lamps have lost their place on the North American market. A number of reasons will, no doubt, have become evident to Mr. Wotton from the discussion, although I hope that it is also evident to him that only a few of these are justified in fact. Another reason, which has not yet been referred to, is that the type of sodium lamp formerly used here was of much lower efficiency than even the older type of separable-jacket lamp used in Europe. This lower efficiency is, I understand, due primarily to the characteristics dictated by the mode of use in series installations.

I share Mr. Wotton's opinion regarding the solid yellow color of sodium lamps in comparison with the anemic yellow color of the yellow mercury lamps.

In regard to Mr. Wotton's reference to lamp life, I would say that generally in Europe quoted lamp lives are indeed often conservative. This is partly bound up with certain clauses in government assisted lighting schemes, etc.

In the case of sodium lamps we have, perhaps, been rather more conservative than usual. This is partly due to the fact that the trend toward much higher efficiencies has forced the development to such an extent that the lamp manufacturers prefer to cumulate more field experience with the new types before raising their published life figures. In the future, no doubt, increases can be expected.

I have only limited information on the two types of lamps mentioned by Mr. Wotton, which are not manufactured by my company.

Mr. Wotton's remarks about the advantages of sodium lamps with regard to size, temperature and choice of materials of the luminaires are confirmed by the experience we have had in Europe with luminaire construction. In a luminaire with simple optical system, using a 200-watt sodium lamp, luminous intensities of the order of 5000 to 6000 candelas are achieved.

I consider higher values than these to be quite unsuitable. They would give rise to unacceptable glare or, when sufficiently deflected downward, to excessive variations in the light cast onto automobile hoods, dashboards, through rear windows, etc. These effects are less disturbing at high lighting levels, but to achieve such levels the luminaires must be placed so close to each other that close beam control and high luminous intensities in the beam lose their significance.

1. de Boer, J. B., Burghout, F. and van Heemskerck Veeckens, J. F. T.: "Appraisal of the Quality of Public Lighting Based on Road Surface Luminance and Glare," *Fig. 7*, a paper presented at the C. I. E. Sessions, Brussels, 1959.
2. Waller, A.: Thesis "Zichtbaarheid" (Visibility), Utrecht, Netherlands, 1945.
3. Jainski, I. P.: "Die Unterschiedsempfindlichkeit des menschlichen Auges bei verschieden Lichtarten," *Lichttechnik 12*, nr. 6, p. 355 (1960).
4. de Boer, J. B. and van Heemskerck Veeckens, J. F. T.: "Observations on Discomfort Glare in Street Lighting: Influence of the Colour of the Light," a paper presented at the C. I. E. Sessions, Zurich, 1955.
5. Ferguson, H. M., Reeves, J. and Stevens, W. R.: "A Note on the Relative Discomfort Glare from Mercury, Sodium and Tungsten Light Sources," *G. E. J. Journal 20*, nr. 3 (1953).
6. Ferguson, H. M. and Stevens, W. R.: "Relative Brightness of Coloured Light Sources," *Transactions of the Illuminating Engineering Society* (London) 21, No. 9 (1956).
7. Balder, J. J. and Fortuin, G. J.: "The Influence of Time of Observation of the Visibility of Stationary Objects," a paper presented at the C. I. E. Sessions, Zurich, 1955.

Errata

An error has been discovered in the technical committee report, "Recommended Practice for Office Lighting," published in the June, 1960, issue of ILLUMINATING ENGINEERING. On page 316, column 3, line 8, the reference to "100- to 140-degree zone" should be "110- to 140-degree zone."

A.I.A. File No. 31f

INSTALLATION AT BAMBI HALL, BROAD AND PORTER STS., PHILADELPHIA, PA.

Lighting a Ballroom

LIGHTING OBJECTIVE: To provide a comfortable atmosphere with variable levels of illumination for dancing, banquet and relaxation-type dining, and meetings.

GENERAL INFORMATION: This completely renovated hall is approximately 55 feet by 65 feet with a 20-foot ceiling height. One corner of the room (left background in photo) has a raised platform for orchestra, performers or speakers. Colors and reflectances of major room surfaces are:

ceiling	light cream	53%	walls	birch	22%
walls	white and light blue stripe	43%	floor	natural finish maple	23%

INSTALLATION: Lighting is provided by the following equipment, manufactured by Litecraft Manufacturing Corp.:

One catalog No. B 139/72, 72-inch Domelite, equipped with one 500-watt PS-40, I.F. lamp. This unit is located in the center of the room and is suspended on a 24-inch stem.

Twelve catalog No. B 139/48, 48-inch Domelites each equipped with one 300-watt PS-35 I.F. lamp. These units are suspended on 24-inch stems and are spaced on 12-foot by 18-foot centers.

Ten catalog No. F 342 recessed louvered downlights, each equipped with one 150-watt R-40 spot lamp. Units are arranged on six-foot centers in a circle around center (72-inch) domelight.

Nine catalog No. H616 bullet-type adjustable units, each equipped with one 150-watt R-40 spot lamp. These units are on 24-inch stem hangers and are located over the raised platform in a triangular pattern.

All of this equipment can be dimmed by motor-driven control dimmers. At full brightness maximum average level of illumination in the center of the room is 75 footcandles. Brightnesses at that time are: ceiling, 5 fL; white and light blue striped walls, 6 fL; birch panel walls, 3 fL; and floor, 14 fL.

Lighting designed by Thomas P. Ferris and George T. Anderson, Jr., Application Lighting Engineers, Philadelphia Electric Co., and Electrical Contractor, Herman K. Solow, all of Philadelphia, Pa.

Lighting data submitted by Thomas P. Ferris and George T. Anderson, Jr. as an example of good lighting practice and to aid in the design of similar installations.

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A.I.A. File No. 31f

Report on . . .

Sixth International Technical Conference on Lighthouses and Other Aids to Navigation

By CLIFFORD F. PEISTRUP

The Sixth International Technical Conference on Lighthouses and Other Aids to Navigation was held in Washington, D. C., during the week of September 26th, 1960. After one week of technical discussions, a second week was spent in visiting various aids to navigation facilities of the Coast Guard and United States industry supporting our aids to navigation requirements. Approximately 300 delegates from 40 nations comprised this technical conference.

These International Technical Conferences were begun in 1929 and have met approximately every five years, except during the war period of 1940 to 1945. The conferences were resumed in 1950 with an increasing attendance at each subsequent meeting.

It is the purpose of this article to introduce to illuminating engineers a new source of technical information which may be useful for a variety of lighting applications. There were a varied cross-section of subjects discussed at the conference, some of which I am sure will interest each of you—whether you be scientist, manufacturer, or administrator. Of the 156 papers discussed at the conference, 47 may be classified as optical in nature, 9 related to power sources, 3 related to fog detection, and various other papers concerned with remote control of unattended light and fog signal equipment, radar, light vessels, buoys, fog signals, electronic navigational devices, administrative procedures, etc.

To cover such a multitude of papers on a variety of subjects, the following procedures were used:

(1) Papers were submitted several months in advance so they could be translated into two languages—English and French.

(2) Papers were distributed to the delegates about three months in advance of the conference to permit adequate study of interested subjects.

(3) Papers were not read at the conference, but discussions were invited after readings of brief abstracts of each paper.

(4) Discussions were limited to a given time to permit discussion of all papers. If additional time was needed, a general discussion period was held at the end of each session, time permitting. For those particular topics requiring additional time, informal sessions were held after hours or official subcommittees appointed to study and report to the executive committee.

(5) To further allow a wide coverage of subjects, joint sessions were held on unrelated subjects, that is, radar was discussed at one panel while light sources were discussed at the second panel.

The subjects of greatest interest as determined from the floor discussion were:

(1) The Blondel-Rey Law or the effective intensity of flashing lights. Special interest was shown for the discharge type light sources where flash lengths in the micro-second region pertain.

(2) Use of Xenon short arc lamps for steady burning and flashing application.

(3) Use of acrylic plastics in minor light application.

(4) Color thresholds.

(5) The influence of color on glare.

(6) Sun or daylight switches for conservation of battery power.

(7) Recent battery developments.

(8) Use of solar power.

(9) Visual range and contrast.

(10) Recent studies of infrared radiation through fog.

One subject pertinent to general lighting was glare and its effect on visual threshold. During the last five years, France, the Federal German Republic, and Russia performed basic experimental work relating to glare and maritime signalling. The variation in visual thresholds for extraneous sources under various background luminances were reported. The German paper also reported the effect of not knowing the source location in determining a practical threshold. The Russian paper included comprehensive tables of contrast data for a multitude of objects and for various background conditions. To illustrate the thoroughness of their work, contrast data were reported for such subjects as a red brick building, white house, barn, against such backgrounds as foliage, coniferous forest, grass, snow and sky.

A new subject introduced to the Conference was the use of fluorescent color systems for aids to navigation use. This report gave a general description of the theory of fluorescent materials and presented technical data comparing fluorescent materials aganinst standard paint systems. The advantages and limitations of fluorescent systems were outlined. This paper was very thorough and very complete as an introduction to the basic theory and use of fluorescent materials; however, information

Author: Lieutenant Commander, U. S. Coast Guard; Chief, Aids to Navigation Section, Testing and Development Division, U. S. Coast Guard. The statements contained in this article are the personal opinions of the author and do not necessarily reflect the official views of the U. S. Coast Guard.

was not available at the writing of this paper to enable one to predict visual range for a given set of conditions. Fortunately, however, Dr. H. Richard Blackwell of Ohio State University completed a study just before the Conference met, which allows one to relate the chromatic contrast data for the fluorescent materials to the conventional luminance contrast data which will allow prediction of visual range in the usual manner, that is, it will allow one to enter Duntley's visibility nomograms to predict visual range as a function of the area of the fluorescent material knowing the contrast and illuminance conditions. Dr. Blackwell's work in conjunction with this paper is a major contribution in this field and should be extremely valuable to those concerned with aircraft marking systems and airport marking.

It was mentioned that various papers related to color were presented. F. C. Breckenridge of the National Bureau of Standards presented a paper on a "Correlation of Signal Color Recognition Tests." In this paper Mr. Breckenridge reviewed the last four significant works in this field and pointed out specific applications to maritime signalling. The Russians presented work on chromatic and achromatic thresholds of point sources under field conditions. France presented some very basic experimental work on color in its study on glare. Germany also did some color threshold work in conjunction with its glare study. The foremost contribution in this field was the work done by Pierre Blaise of France. In his paper he presented experimental evidence that violet can be recognized as a true color right down to the photopic threshold. To date, white and possibly red were the only two colors that could be recognized at photopic threshold. Monsieur Blaise attributes his discovery to a very pure light source with very little red or blue. In this study of violet he used a mercury lamp with a special dark cobalt glass filter. He concluded that it may be possible to add violet to the present red and green colors now used in maritime signalling. This paper will be of considerable interest to those concerned with color applications in lighting.

One paper presented to the Conference treated the application of retroreflective materials on aids to navigation. Definitions peculiar to retroreflectors were introduced along with the basic theory. The definitions used in this report were proposed for consideration as standard definitions to be used by lighthouse authorities. Various types of retroreflective materials were described. The main contribution of this paper was the presentation of a formula and curves for predicting visual range knowing the area of the retroreflective material and assuming the intensity of the projector or searchlight and the threshold of the eye for any given value of transmissivity. Curves were plotted for several values of transmissivity. This paper answers the practical question: "How far can I see an object which has been treated with retroreflective material?"

Far down on the list of active subjects was the propagation of infrared radiation in natural fog. One paper from Japan and one from Germany presented work on this subject. The German paper stated that the experimental results could not be verified theoretically due to the lack of experimental data on the radii of the water droplets in natural fog. Ironically, buried in a paper on sound presented to this same Conference were data on the statistical distribution of water droplet radii in natural fog—the exact data the experimenter needed. Since this experimenter was not interested in sound, he was unaware of the existence of these data. It was the thought of this example that prompted the writing of the present article.

A Swedish paper was entitled "A New Light System for Landfall Lights Using Sealed-Beam Lamps." With specific interest to signal lighting, perhaps it could have been entitled "The Revolving Light That Doesn't Revolve." Actually the paper describes a method of using sealed-beam lamps to provide complete sector coverage for a lighthouse. Sector coverage means different colored sectors or sectors of different intensity. Magnetic switching circuits provide voltage to the various lamps in a planned sequence so as to give the effect of a revolving beacon. The entire lighting system has no moving parts and it was this factor which was the primary consideration in designing this unattended lighthouse for maximum reliability.

How many are interested in using a decibel notation for a new light intensity unit? I am sure that within the next five years some of you will be questioned as to your opinions. At this Conference two delegates of the French Lighthouse Service made two proposals — the adoption of a decibel notation method for indicating light intensities in "List of Lights," and the adoption of a method by which navigators can forecast the luminous range of a light under various meteorological conditions. Preliminary discussions on the two proposals were generally favorable and the matter has been referred to a working committee for study and solicitation of international opinion. Whether such a logarithmic light intensity unit would remain peculiar to lighthouse engineering or finally adopted by recognized lighting groups or standards societies is merely academic at this time.

With lighthouse intensities now up to 500 million, one can see that the mathematics of such large numbers in working formulae can become a little tedious. Also wouldn't the decibel units give the mariner a relative scale of light units more sensible to his everyday concepts of comparative scales? For example, a 10,000 candlepower light may be represented by 40 decibel units and a 100 million candlepower light by 80 decibel units. For atmospheric conditions with a transmissivity of 0.7, the 10,000-candlepower source is visible 13 nautical miles and the 100-million candlepower source, 33 nautical miles. Thus, for this example, a doubling of decibel units of intensity represents about a two and one-half times increase in visual range. One unfamiliar with Allard's Law, which relates intensity to visual range, intuitively thinks that the light 10,000 times brighter will be seen considerably farther. Thus, the introduction of the new decibel unit will give a more realistic glance of the relative effectiveness of a light as an aid to a mariner. If any readers have any opinions on this subject, the author would appreciate comments.

Another subject which may be indirectly related to

lighting is the remote control of diesel-engine generators and aids to navigation equipment. Whether it be sun-operated switches for conservation of battery power or the more sophisticated multi-channel radio-controlled system for monitoring beacons, fog signals and standby equipment, there are a variety of control methods described and discussed. A United Kingdom paper described an elaborate combination land-line and radio link remote control system. Control of up to 16 stations is provided from a single command unit. Coded pulses are transmitted into voice frequency tones and used to transmit the signals. These include 14 control operations and 25 indication operations at the central control. Step-by-step progress of equipment signal action is indicated. Many "fail-safe" features of the system were described. A Swedish paper discussed a remote control system using very low, sub-audible frequencies, and a Canadian paper described a radio dial system. This system, when connected to a radio receiver, switches the equipment on or off upon the reception of appropriate two-digit numbers which are keyed into a radio transmitter by a telephone dial mechanism.

Under what conditions are signal lights turned on during daylight hours? In reference to lighthouses, I can introduce you to the methods used in various countries in determining when to turn on the main lights at lighthouses during hours of reduced visibility. In some foreign countries it is customary to turn on the light whenever the fog signal is in operation. This is determined by the light keeper looking at a given object by day. When the object disappears from view, the fog signal and light are turned on. The U. S. Coast Guard has made a study of this problem. The results showed that where a lighthouse is at an average distance of one mile, it is worthwhile to turn on the light when the fog signal is on, if the light intensity is equal to or greater than 50,000 candlepower. Of course, if a dangerous navigational circumstance exists, the light is turned on whenever the fog signal is in operation regardless of the candlepower. This study may be found in U. S. Coast Guard Civil Engineering Report No. 11.

Those interested in new optical designs might be interested in the German paper on two types of aspherically ground optics, a British paper on an unattended beacon with a revolving plastic lens, or a new 250-mm acrylic lantern with twin directional beams. The German paper discussed two aspherically ground glass optics. One is dioptric and accepts a solid angle of 3.3 steradians from the light source. The second design is catadioptric and accepts light from a hemisphere or 6.3 steradians. This design was for a directional narrow beam application and was capable of providing 80,000 beam candlepower with a 12-volt 20-watt lamp. The British beacon has a lens assembly consisting of two six-sided lens sections mounted vertically one over the other. Various light characteristics are available by varying the relative alignment of the two lens sections. The lantern assembly, turntable and power system are described. The power system is unique in that it utilizes a transistorized oscillator and amplifier unit to provide the d-c to a-c conversion for turntable operation.

At the conclusion of this conference it was announced that the U. S. Coast Guard will join the International Association of Lighthouse Authorities. This organization was formed in 1957 and provides a means of officially exchanging views on lighthouse matters. It also provides a technical service to member nations and processes the distribution of technical papers presented before the Lighthouse Conferences. In addition, IALA can appoint committees to study common lighthouse problems—whether they be technical, operational, or administrative. A primary task of the International Association of Lighthouse Authorities is to coordinate the activities of the International Technical Conferences and publish the conference reports. It has been announced that the next conference will be in Rome, Italy, in 1965.

All papers presented at this conference are available in limited numbers. For those interested in obtaining information on specific papers, an abstract of reports has been published and is available to those interested in signal lighting. Those having access to Armed Services Technical Information Agency (ASTIA) Bulletins may find complete abstracts of all reports in *ASTIA Technical Abstract Bulletin Number U 60-4-3*, dated 1 November 1960. All reports were listed under the heading of Navigation (Division 19). The abstract of reports is also available from the Secretary, Sixth International Lighthouse Conference, Commandant (ETD), U. S. Coast Guard, Washington 25, D. C.

Copies of all reports are available through the U. S. Coast Guard or the Armed Services Technical Information Agency (ASTIA).

Register Now for Your Regional Conference

IES Regional Conferences, now underway, offer the lighting man one of his best opportunities for up-dating practical lighting knowledge—through sessions filled with information on the latest developments in lighting products and practices.

A list of the 6 remaining conferences will be found on page 46A. Write to your Regional Conference Chairman now to register for these important lighting meetings.

Views and Opinions

Base Bid Specification in Lighting—Its Benefits and Limitations

A "base bid" type of specification is one where the equipment is clearly defined as to appearance, capacity, function, performance, and quality. In addition, it is specifically identified with a manufacturer's name, model, number, and catalog listing. Under this type of specification, the bidder has no selection of equipment under his base bid. All contractors are obligated to bid on the exact equipment called for, except as supplementary instructions outlined in the specification may permit.

It should be emphasized that under a base bid specification the selection of what type or brand of lighting equipment is to be used does not depend on the contractor's decision but rests solely in the hands of the architect, engineer, and owner, which is as it should be. If the owner chooses to accept an alternate proposal, then any price differential will be credited or charged to the cost of the project, because the cost of the alternate will be known exactly. From the engineer's point of view, if the acceptance of an alternate requires additional engineering services, the costs of these services can be determined and a true evaluation of the worth of any alternate can be established, prior to its acceptance by the owner.

The prices received under a base bid are usually very close because the only variable factors are the costs of installation facilities and labor. Each contractor knows exactly what he must furnish, and he realizes that his competition must also furnish exactly the same lighting equipment.

This type of specification makes it possible for the engineer to do a complete and accurate detailed drawing and assures the owner that if the base bid is accepted, his lighting installation will bear something more than a coincidental resemblance to the plans. If plans are prepared with the finesse that a base bid specification permits, the accuracy with which a bidder can estimate the work is increased tremendously. Contingencies to cover questionable items of material or installation are all but eliminated. The savings thus obtained will more than offset a reasonable profit factor for all parties concerned. The finished work will always reflect the pride of the contractor and the supplier in a profitable undertaking. Furthermore, since a base bid precludes "shopping for price," unnecessary delays in delivery of equipment and installation are minimized. Another desirable aspect is that suppliers of equipment can bid at a reasonable profit and hence are apt to be most cooperative on delivery, guarantee, and service.

It must be understood that there may be very legitimate reasons for any bidding contractor to raise objections to using the equipment specified in the base bid. It is possible that the contractor has had difficulties on another project where the specified equipment was used, in which case he may balk at guaranteeing an installation of equipment in which he has no confidence. There is also the possibility of personality differences between the contractor and supplier which can and do assume unusual proportions. Therefore, it is mandatory that base bid specifications make some provision for any bidding contractor to offer alternate brand names of lighting equipment for the engineer's and owner's consideration. However, procedures set up for the offering of alternates should require some documentary work on the part of the bidding contractor so as to discourage promiscuous deviations from the base bid specifications except for unusual circumstances or justification.

A common objection to the base bid specification is that it is not an impartial specification, and the act of limiting the equipment to a specific manufacturer implies a very definite preference on the part of the engineer. The continual use of the products of one manufacturer would invariably result in the engineer being accused of collusion with the supplier and the manufacturer, and the associated stigma of being a percentage or commission man. An engineer policy of rotating the base bid specification from one manufacturer to another for each successive project, and the frequent acceptance of justified alternate bids goes a long way in quieting these objections from bidders, suppliers, and manufacturers. To most engineers, a lighting equipment manufacturer's reputation for workmanship, honesty, and integrity is often more important in the selection of a base bid than is the equipment itself. The selection of any manufacturer's equipment, honestly and sincerely arrived at, should be expressed and defended instead of hiding behind the skirts of subterfuge and hypocrisy—so-called "impartiality."

One of the greatest contributions that the architect's consulting engineer can make to the lighting industry is to abandon the farce of impartiality in the plans and specifications for any project; to have the courage to name a preference exactly and specifically; to have the dogged tenacity to insist on enforcement thereto; and to fight whatever stigma may be associated with such action. The engineer who has pride in his profession, confidence in his own judgment, and the courage to fight for his convictions will set the pattern for making today's dream become tomorrow's reality.—DANIEL S. GAIDOSZ, *Consulting Engineer, West Haven, Conn.*

Symposium Session Highlights

Comfortable Visual Environment—(l. to r.) C. L. Crouch, moderator, Carl W. Evans, H. E. D'Andrade, George W. Clark.

World Lighting—Willard C. Brown, moderator, Ruby Redford, Abe H. Feder.

Street Lighting—Newbold Morris, Edmond C. Powers, moderator, Jerome J. O'Neill, Stacy Standley, E. B. Karns.

Esthetics—Robert W. Dowling, moderator, Rollo Gillespie Williams, Jean Rosenthal, Joel Rubin.

◄ Success of Higher Footcandle Levels in Offices, Industry, Institutions—Henry J. Wald, moderator, C. L. Amick, E. A. Linsday.

Lighting, Heating, Air Conditioning — Douglas Haskell, moderator, Murray Quin, Robert Gand (for B. S. Benson, Jr.). ►

Outdoor/Recreational Lighting—W. E. Cummings, moderator, J. R. Chambers, W. W. Weld, Thomas Smith Kelly.

Residential—C. L. Amick, general moderator, Judith Newman, session moderator, S. R. Shemitz, Elizabeth Meehan.

LIGHTING NEWS

Symposiums at National Lighting Exposition Attract Total Attendance of 1710

Nine symposiums, constituting the World Lighting Forum held in connection with the National Lighting Exposition, turned out to be one of the year's best lighting conferences. This constructive program, featuring top speakers in nine hot lighting subjects, attracted audiences totalling 1710. Question and answer periods provided further education to the large numbers of architects, engineers and others attending.

The Forums were held at the New York City Coliseum every day March 6 through 8, just preceeding the daily 1 p.m. opening of the Exhibit Hall, which featured the display of new developments of some 250 lighting equipment manufacturers. Total attendance at the successful four-day lighting trade show was 16,663.

The series of nine symposiums was developed by an honorary committee of six. Participating in this planning were: William H. Keen, Past Chairman of New York Section of IES, an illuminating engineer with the New York office of General Electric; Miss Ruby Redford, editor of ILLUMINATING ENGINEERING; Berlon C. Cooper, eastern editor of *Electrical Construction and Maintenance*, McGraw-Hill Publishing Co.; John Freeman, chairman, sponsor show committee, Advance Transformer Co.; Robert L. Davis, editor of *Contractors' Electrical Equipment* magazine; and Carl Evans, editor, *Lighting*, W. R. C. Smith Publishing Co.

Symposium Program

Over-all moderator for all nine sessions was George J. Taylor, vice-president for marketing, research and development, Day-Brite Lighting, Inc., St. Louis, Mo.

The program was opened on March 5 with a Keynote Address by IES President, Richard G. Slauer, manager of engineering, Fixture Division, Sylvania Electric Products Inc., Wheeling, West Va. It continued March 6 to 8 with extraordinarily successful daily symposiums planned particularly to provide new information developing from new illumination levels, new lighting techniques, and recent concepts in lighting application. The experts presenting this information were:

Integration of Lighting, Heating and Air-Conditioning

Moderator: Douglas Haskell, editor of *Architectural Forum*.
Speakers: Robert Gand for B. S. Benson, Jr., Benjamin Division, Thomas Industries, Inc., Des Plaines, Ill.; M. L. Quin, Day-Brite Lighting, Inc., St. Louis, Mo.

Success of the New Recommended Higher Footcandle Levels for Office, Industrial and Institutional Lighting

Moderator: Henry J. Wald, consulting engineer, Wald & Zigas, New York, N. Y.
Speakers: Charles L. Amick, Day-Brite Lighting, Inc., St. Louis; E. A. Linsday, General Electric Co., Cleveland, Ohio.

Creation of Comfortable Visual Environment

Moderator: C. L. Crouch, technical director, Illuminating Engineering Society.
Speakers: Carl W. Evans, editor of *Lighting;* H. E. D'Andrade, General Electric Co., New York City; George W. Clark, Sylvania Electric Products Inc., Wheeling, West Va.

New Light Sources and Their Application

Moderator: George J. Taylor.
Speakers: A. K. Gaetjens, General Electric Co., Cleveland, Ohio; William S. Till, Westinghouse Electric Corp., Bloomfield, N. J.; Theodore C. Sargent, Sylvania Electric Products Inc., Salem, Mass.

The Importance of Adequate Street Lighting

Moderator: Edmond C. Powers, Educational Director of National Street and Highway Safety Lighting Bureau.
Speakers: The Honorable Newbold Morris, Commissioner of Parks, New York City; Jerome J. O'Neill, director of the Greater New York Safety Council's Traffic and Transportation Division; Stacy Standley, product manager, Line Material Industries, Milwaukee, Wis.; Edgar B. Karns, product manager, Westinghouse Lighting Division, Cleveland, Ohio.

Outdoor and Recreational Lighting

Moderator: William C. Cummings, Jr., sales application engineer, Public Service Electric and Gas Co., Newark, N. J.
Speakers: James R. Chambers, sales manager, Appleton Electric Co., Chicago, Ill.; Thomas Smith Kelly, lighting consultant, New York City; Wallace W. Weld, chief application engineer, Revere Electric Manufacturing Co., Chicago, Ill.

Residential Lighting

Moderator: Judith Newman, architectural department, *Living for Young Homemakers* magazine.
Speakers: Sylvan R. Shemitz, president,

OPENING SESSION of the symposium held in conjunction with the Third National Lighting Exposition, March 6-8 at the New York City Coliseum. At rostrum, General Symposium Chairman George J. Taylor, Past-President of IES; seated center, Keynoter Richard G. Slauer, IES President; right, Douglas Haskell, editor of *Architectural Forum*, moderator of the first symposium—integration of lighting, heating and air conditioning.

C. S. Mersick Electric Supply Corp., West Haven, Conn.; Elizabeth Meehan, residential lighting consultant, Philadelphia Electric Co., Philadelphia, Pa.

Esthetics of Lighting for Entertainment, Theatre, High School Auditoriums, Art Objects

Moderator: Robert W. Dowling, president and director of City Investing Co., New York City.

Speakers: Rollo Gillespie Williams, lighting consultant and director of color research, Century Lighting, Inc., New York City; Joel E. Rubin, director of theatrical lighting division, Kliegl Brothers Lighting, New York City; Jean Rosenthal, president of Theatre Production Service, lighting and production (theatre) designer.

World Lighting and Its Effects

Moderator: Willard C. Brown, IES Medallist, Past-President of IES, and retired applications engineering manager, General Electric Co., Cleveland, Ohio.

Speakers: Abe H. Feder, Lighting by Feder Inc., noted designer of lighting for stage productions, numerous buildings and fountains; Ruby Redford, editor of ILLUMINATING ENGINEERING.

Rochester Section Sponsors Press Tour of RG & E Relighting

Some 25 editors of major trade and professional magazines converged on Rochester, N. Y. on February 22, to see the "heating with light" project now being undertaken in the relighted Rochester Gas & Electric Building. Sponsor of this demonstration-lecture tour was the Rochester Section of IES. The all-day meeting was also attended by approximately 200 members and guests of the Section.

Full details of this extraordinary installation will be the subject of a paper at the National Technical Conference in St. Louis next September. Trade press editors, however, and local IES members enjoyed a preview of this pace-setting installation which completely relights a 35-year old building to some 240 footcandles, all carefully engineered to achieve visual comfort and efficiency. The installation was of particular interest to visiting executives, architects, contractors and others, however, as a practical example of the integration of lighting, heating and cooling. Much of the building's heating requirements will be supplied by the lighting system.

The Rochester Section also sponsored a splendid "Washington's Birthday" luncheon at the Rochester Club, as part of its all-day meeting. Speakers at the luncheon outlined the several features of this outstanding modernization project. Moderator for this analysis was Lester C. Twichell, commercial sales manager of RG & E (and a past Regional Vice-President of IES). Realto Cherne, consulting engineer for the project, gave details on the heating and air-conditioning systems, and discussed the economics of the integrated system approach in this modernization of an old building. Other speakers at the luncheon, and later at a press question-session, included Kirk M. Reid, Past-President of IES and manager of lighting education for General Electric Co., Nela Park, Cleveland, Ohio; and Arthur C. Barr, a director of IES and manager of product planning and application engineering for G. E.

Each of the three floors so far completed in the relighting program uses a different lighting design, though each is in excess of 200 footcandles and employs the integration of lighting, heating and cooling. Visitors present at the demonstration voted on their preferences among these three designs. One of these three methods wil be adopted as the final layout for the remaining seven floors still to be completed.

INTEGRATED lighting, heating and air conditioning for the modernization of the Rochester Gas & Electric Co. Building was demonstrated to some 200 IES members and guests and 25 trade press editors, shown here at the luncheon session of the all-day meeting on February 22.

Emeritus Members and Fellows of IES

Emeritus status is conferred by Council upon Members and Fellows of IES who have retired from regular occupation "after having performed for the Society services of such meritorious character as the Council may deem worthy of this honorable reward." Those honored with Emeritus grade are exempt from payment of dues and entitled to all privileges which they were accorded as Members or Fellows.

Those in Emeritus grade, as of March 8, 1961, were:

ANDERSON, EARL A. (Michigan Section), 19218 Berkeley Rd., Detroit, Mich.

ATHERTON, C. A. (New York Section), P. O. Box 1137, Mattituck, L. I., N. Y.

BEALS, G. W. (Connecticut Section), The Miller Co., Meriden, Conn.

BEAR, W. P. (Southern California Section), 8344 Lullaby Lane, Van Nuys, Calif.

BENEDICT, A. I. (San Diego Section), 800 First St., Coronado, Calif.

BERRY, C. J. (Maryland Section), 3 Severn River Rd., Severna Park, Md.

BRYANT, J. M. (Eastern Pennsylvania Section), 1534 Quarry Lane, Lancaster, Pa.

CRAVATH, J. R. (Diablo Section), 2152 Ward St., Berkeley, Calif.

DANIELS, JULIUS (New England Section), Centerville, Cape Cod, Mass.

DICKERSON, A. F. (Florida Section), 1455 Harbor Dr., Sarasota, Fla.

DOLKART, LEO (Chicago Section), 222 E. Chestnut St., Chicago, Ill.

DOWS, C. L. (Cleveland Section), 1855 Charles Rd., East Cleveland, Ohio.

FALGE, R. N. (Indiana Section), R. R. #2, Box 305, Anderson, Ind.

FORSYTHE, W. E. (Cleveland Section), 15006 Terrace Rd., East Cleveland, Ohio.

GIBSON, K. S. (Capital Section), 4817 Cumberland Ave., Chevy Chase, Md.

HALBERTSMA, N. A. (Non-Section), Laan van Rijnwiik 1, Zeist, Holland.

HASTINGS, M. B. (Toronto Section), Powerlite Devices Ltd., 54 Atomic Ave., Toronto, Ont.

HIBBEN, S. G. (New Jersey Section), 31 Clinton Ave., Montclair, N. J.

HOGUE, O. R. (Chicago Section), 115 Michigan Ave., Highwood, Ill.

HOLLADAY, L. L. (Virginia Section), 1713 Jefferson Park Ave., Charlottesville, Va.

HORN, CAROLINE E. (Housatonic Chapter), Florida Rd., Ridgefield, Conn.

HORTON, F. G. (Michigan Section), Engineering Society of Detroit, 100 Farnsworth Ave., Detroit, Mich.

JAMES, L. V. (New York Section), 9 Forest Lane, Scarsdale, N. Y.

KAUFFMAN, P. F. (Chicago Section), 2476 W. Estes Ave., Chicago, Ill.

(Continued on page 12A)

The nearsighted MISTER MAGOO says . . . "1945? Who could forget that year? Eagle-eye Magoo was mustered out of the Aircraft-Spotting Command, and General Electric invented the slimline lamp. Happy birthday, Slimline! Zounds —they don't make these telescopes like they used to!"

3 reasons why General Electric Slimline is America's most popular 8-foot fluorescent

Any time you see a long, unbroken line of fluorescent light, chances are good it's a General Electric Slimline lamp. Over the years, the G-E Slimline has proved . . .

1. *Your customers can cut parts maintenance almost in half.* A G-E Slimline system has about half as many parts as a standard 40-watt system, yet it produces the same amount of light.

2. *Your customers get 5% higher efficiency* from General Electric Slimline lamps than from standard 40-watt fluorescents. They get more light for every dollar of electricity.

3. *Your customers can make their places look better.* Slimlines start instantly, with no blinking. They have an excellent record of uniformity and long life because of General Electric's outstanding quality controls and manufacturing experience. Available in all popular colors.

There are 14 combinations of tube length and diameter to fit anyone's space requirements. Recommend General Electric Slimline lamps on your next job. General Electric Co., Large Lamp Dept. C-13, Nela Park, Cleveland 12, Ohio.

Progress Is Our Most Important Product

GENERAL ELECTRIC

(*Continued from page* 10A)

KENT, L. C. (Cleveland Section), 3459 Colton Rd., Shaker Heights, Ohio.
KETCH, J. M. (Cleveland Section), 991 Roanoke Rd., Cleveland, Ohio.
KINNEY, R. C. (Kentuckiana Chapter), 2705 Riedling Dr., Louisville, Ky.
LITTLE, W. F. (New York Section), 75 Dalton Rd., Yonkers, N. Y.
LUCKIESH, MATTHEW (Cleveland Section), 21175 Shaker Blvd., Shaker Heights, Ohio.
MACDONALD, N. D. (New York Section), 60 Hill Terrace, Yonkers, N. Y.
MAGDSICK, H. H. (Cleveland Section), 159 Van Aken Blvd., Shaker Heights, Ohio.
MAISONNEUVE, HENRI (Non-Section), 217 rue de l'Université, Paris, France.
MURPHY, F. H. (Oregon Section), 4213 N. E. 32nd Ave., Portland, Ore.
ODAY, A. B. (Florida Section), 639 59th Ave., St. Petersburg Beach, Fla.
PORTER, L. C. (Connecticut Section), 121 Gen St., Kensington, Conn.
PRIDEAUX, G. F. (Florida Section), 528 15th Ave. South, Naples, Fla.
RANDALL, W. C. (Michigan Section), 770 Shirley Dr., Birmingham, Mich.
ROLPH, T. W. (Southern California Section), 1465 San Pasqual St., Pasadena, Calif.
SHEIBLEY, F. D. (Eastern New York Section), Box 372, Philmont, N. Y.
STAIR, J. L. (Chicago Section), 1734 E. 72nd St., Chicago, Ill.
TAYLOR, A. H. (Cleveland Section), 16304 Helmsdale Rd., East Cleveland, Ohio.
TILLSON, E. D. (Chicago Section), 2507 Lincoln St., Evanston, Ill.
WATSON, L. M. (San Diego Section), 4176 Arden Way, San Diego, Calif.
WEITZ, C. E. (Cleveland Section), 1848 Hillside Rd., East Cleveland, Ohio.
WESTERMAIER, F. V. (Philadelphia Section), 400 King's Highway East, Haddonfield, N. J.
WILLIAMS, S. B. (New England Section), Brooks St., Jamestown, R. I.

Midwest Electrical Trade Show Scheduled for May 2-4 in Chicago

The Sixth Biennial Midwest Electrical Industry and Lighting Exposition, to be held May 2-4 at McCormick Place in Chicago, is expected to have approximately 175 exhibitors, according to an announcement by the show's sponsors. Exhibits will be in two categories—lighting fixtures and component parts for industrial, commercial, residential and outdoor areas and electrical devices, materials, apparatus and equipment used in the construction and industrial fields. The latter category includes electric space heating equipment, industrial appliances, welding, electronic and industrial communication equipment.

COMPLETING organization plans for Rocky Mountain Residence Lighting Forum in Denver are, left to right, seated: Frances Beason, secretary, Fred Rosenquist, executive board; Harold Brandt, chairman; Helen K. Fields, public information chairman. Standing: Bob Walsh, program chairman; Bill Campbell, treasurer; Don Abseck, membership chairman.

The Exposition, formerly called the Chicago Electrical Industry Show, is being conducted exclusively for the trade, with no admission to the general public. Co-sponsors are the Electric Association of Chicago and the Electrical Maintenance Engineers of Chicago.

Invitations have been sent to industry executives, architects, consulting engineers, contractors and distributors and attendance at the show is expected to approach 125,000.

Denver Residence Forum Launched 14th in Active Operation

Latest addition to the roster of IES Residence Lighting Forums is the Rocky Mountain group, recently chartered in Denver, Colo. Potential membership of the group is reported as 200, with 87 attending the first program meeting. Officers of the Forum, elected to serve until September 30, 1961 are: Chairman, Harold E. Brandt, Westinghouse Electric Corp.; Vice-Chairman, Gladys Kline, Bill Kline Associates; Secretary, Frances Beason, Poindexter Electric Co.; Treasurer, William M. Campbell, Pryor Realtor representative; Executive Board, Fred H. Rosenquist, Public Service Co. of Colorado and Don Kingston, Academy of Lighting Arts.

Theme of the Forum's first regular meeting, held on February 9 at the Public Service Co. of Colorado guest center, was the various aspects of controlled lighting. Miss Rose Coakley, lighting consultant of the Superior Electric Co., Bristol, Conn., demonstrated the many uses of dimming for achieving changes in room atmosphere.

The 87 people who attended the first meeting, many of them graduates of the Academy of Lighting Arts, represented every phase of the home building industry except financing.

First NEMA Western Conference To Be Held in Los Angeles

The National Electrical Manufacturers' Association has announced plans for its first western conference, scheduled for June 8 and 9 at the Biltmore Hotel in Los Angeles. Intended primarily for NEMA member companies located west of the Rocky Mountains and western representatives of companies headquartered in other parts of the country, the conference is being planned under the direction of co-chairmen A. Arval Morris, president, Electra Motors, Inc., Anaheim, Calif., and Raymond M. Waggoner, west coast vice-president, Hubbard and Co., Emeryville, Calif.

Preliminary program plans for June 8 include a luncheon meeting for sales allies of electrical manufacturers and a general meeting with guest speakers on such topics as the world market for electrical products, research and development, effects of imports on the electrical industry and current and future business trends. An executive session on the second day of the meeting will be devoted

(*Continued on page* 17A)

Glass for lighting

CORNING'S ANSWERS TO A FEW LIGHTING PROBLEMS

PYREX® TUBES PROTECT TUNNEL LAMPS

A number of the traffic tunnels in this and other countries are now protecting their fluorescent lighting with a special PYREX brand glass tube.

The glass tube, with its smooth, hard surface, protects lamps and electrical connections from the detergents commonly used to clean these tunnels.

In most of these installations two fluorescent lamps are placed end to end in a tube in the maintenance shop. The maintenance crew take a load of these tubes down into the tunnels and replace burned-out lamps in a fraction of the time formerly needed. It takes just seconds to remove one tube and insert a fresh one.

Can we help you simplify your lighting requirements with glass by Corning?

4000°K LIGHT WITH ONLY 2°C HEAT RISE

We make a clear glass reflector which can be coated to correct the light from an incandescent lamp to make it equivalent approximately to the light from a 4000°K source.

The coated unit reflects visible light, but lets the infrared pass right through. The resulting light is so cool, it causes only negligible heating.

This particular reflector is for a dentist's lamp. It provides a narrow band of light of unusually uniform intensity while keeping both patient and dentist cool.

The reflector in this application is curved and has twenty-eight distinct optical sections. Each of the twenty-eight reflects light across the entire work area, so the dentist gets uniform lighting despite his hand and instrument movements.

If you would like to delve further into color-correcting, infrared-blocking reflectors and filters, check the coupon.

WE MAKE THE LENS FOR THE "BRUTE"

This is the largest lens used in movie set lighting. It's a full twenty-four inches across. The lamp it fits on won an Academy Award for its maker, Mole-Richardson.

Figure the expanse of the lens and the heat generated by a carbon arc when you feed it 225 amperes, and you'll appreciate the fact that only a PYREX brand glass would do the job at reasonable cost.

It's not really surprising that we can make such a monster, although it takes special equipment to make the "Brute."

Quality is a must! We put each and every lens of this type we make on a photometer to make sure it delivers the actual candle power you specify in the pattern you want.

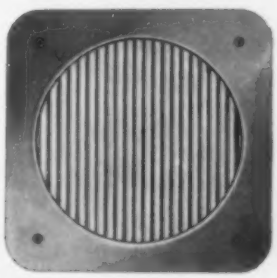
We can colouver the risers of our lenses to reduce brightness in your glare zones.

We can match these lenses with a full range of color filters.

We can put an infrared reflecting coating on them to take the heat out of your light.

Try us the next time you have a lighting problem, big or small, simple or complex.

LIGHTING SWIMMING POOLS IS NO PROBLEM



When you want light in a wet environment, PYREX brand glasses recommend themselves almost automatically.

Here are glasses which can take the corrosive influence of water and chlorine and the like without pitting or clouding or wearing away.

Here are glasses that can take the thermal shock of a 1500 watt lamp lit suddenly on a crisp spring evening.

Here are glasses that take hard knocks.

Here are glasses whose secrets we know well, so we can manufacture a new item in mass quantities quickly at a pleasing price.

Perhaps these are the reasons so many of our swimming pools are lit with the help of PYREX brand glasses.

If you are in this market, we would like to demonstrate our capabilities not only in the manufacturing area but in such allied fields as optical design, colors, etc.

CORNING MEANS RESEARCH IN GLASS

CORNING GLASS WORKS, 6104 Crystal Street, Corning, N.Y.

Please send more information on:

- ☐ Fluorescent lamp tubes
- ☐ Color-correcting reflectors
- ☐ Lenses
- ☐ Swimming pool lenses

Name..... Title.....

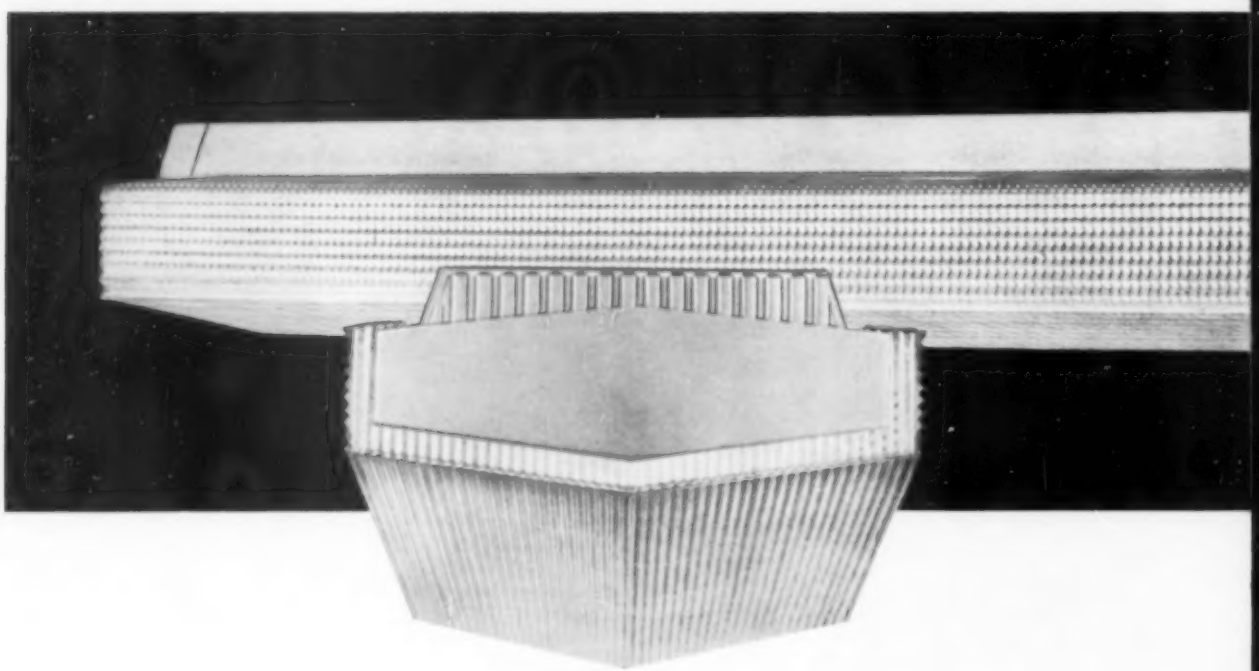
Company.....

Address.....

City..... Zone..... State.....

This is Opticon...a fixture designed to prove that a modest budget need not mean the sacrifice of lighting performance, aesthetic standards, or top quality construction. The lens, for instance, is injection molded in a single, crystal-clear unit 48″ long. Secured by safety hinges, it swings away from either side for fast relamping without the use of tools. Its sides are patterned both inside and out with prisms that run at cross directions. The result is diffused peripheral lighting on ceiling areas for

THIS NEW FIXTURE HAS



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Albuquerque:
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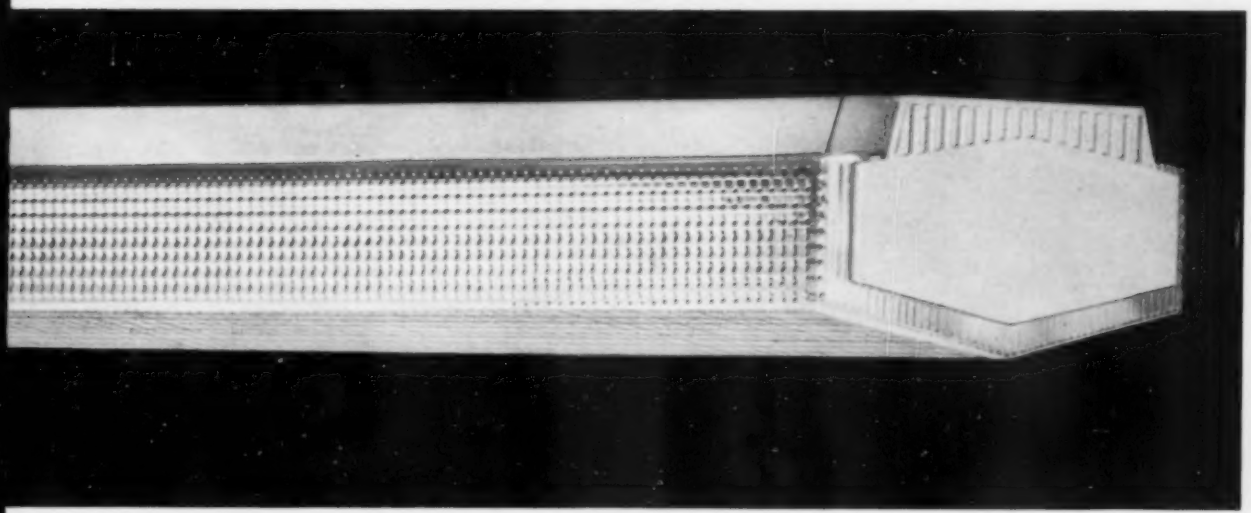
low brightness contrast. The bottom throws wide-angle, glare-free task light downward through sharply molded, brightness engineered prisms. Other noteworthy features include: interlocking ends for arrow straight continuous runs (no dark joiner straps required); slim 4½″ depth; completely enclosed construction to keep fixture cleaner longer; one lamp and two lamp models. Trim, efficient, handsome… its economy will surprise you. Available either stem or surface mounted in 48″or 96″ lengths.

A MULTI-FEATURE LENS



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Gold Seal Elec. Sup. Co.
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Wally Elec. Sup. Co.
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Wilkes-Barre: Anthracite Elec.

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Providence: Leavitt Colson Co.

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TENNESSEE
Knoxville: Square Elec Sup. Co.
Memphis: Belvedere Lighting Co.
Nashville: Nashville Elec. Sup. Co.

TEXAS
Dallas: Rogers Elec. Sup. Co.
Ft. Worth: Anderson Fixture Co.
Cummins Supply Co.
General Industrial Sup. Corp.
Houston: Anderson Lighting Co.
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Southern Electric Supply Co.
Worth Elec. Sup. Co.
San Antonio: Southern Equip. Co.
Strauss-Frank Co.

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Salt Lake City: Artistic Lighting

VIRGINIA
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Lynchburg: Mid-State Elec. Sup. Co., Inc.
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Roanoke: Roland Co.

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Huntington: West Virginia Elec. Co.
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Appleton: Wisc Northern Co.
Eau Claire: W. H. Hobbs Sup. Co.
La Crosse: W. A. Roosevelt Co.
Milwaukee: Electri-Craft Lighting
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Standard Elec. Sup.

WASHINGTON
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CANADA
Montreal: L. D. G. Products, Inc.
The Gray Elec. Co.
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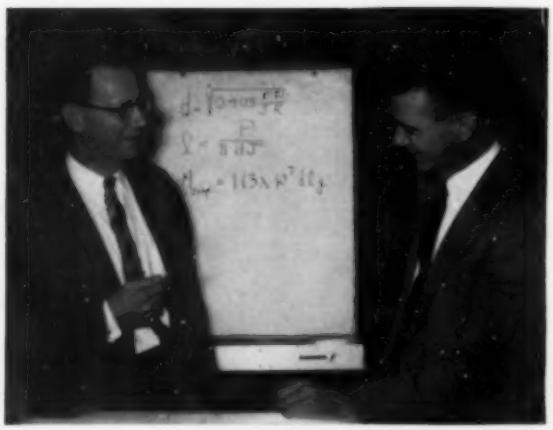
Toronto Ltg. Studios

Here and There With IES Members

Officers of Sections and Chapters in South Pacific Coast Region met with RVP Roy Kreyser (seated, third from right) in Monterey, Calif. for discussion of local activities. Membership problems, program planning and local publicity campaigns all came in for spirited discussion.

Northeastern Regional Conference Committee planning for June 8-9 meeting at Berkeley Carteret Hotel, Asbury Park, N. J. Left to right: Harvie Sykes, hotel committee Eugene Bataille, reservations; R. B. Coles, transportation; R. L. Zahour, regional vice-president; Richard Townsend, finance; Bruce Jensen, general conference chairman; Clyde Nordheimer, entertainment; Frank C. Infanger, program; Louis R. Polzer, publicity; Seymour Bueck, lighting and display.

Dimming as a tool of home lighting was subject of a talk by Rose Coakley, Superior Electric Co., at Michigan Residence Lighting Forum workshop. Also on the program was Harry Robbins, General Electric Co., with a talk on light sources. Fifty-one members and guests attended the afternoon session; 49 were at the dinner program.



Robert R. Wylie (left), Sylvania Lighting Products, Salem, Mass., is shown here with Coastal Bend Chapter member, Bruce Hurley, after his talk, "Let's Be Sensible About Lamp Ratings," at a recent meeting of the Chapter in Corpus Christi, Texas. Mr. Wylie is a member of the IES office and roadway lighting committees.

OPENING meetings of fundamentals of illumination courses in Garden City, New York (left) and Wichita Falls, Texas, being conducted under the sponsorship of the New York and North Texas Sections, respectively.

Enrollment in each course is 25. Coordinator for the eight-session Texas course is Clayton E. Owen, Texas Electric Service Co.; for the ten-session New York course, J. F. Dickerhoff, Long Island Lighting Co.

(Continued from page 12A)

to NEMA organizational operations, particularly in the Far West and the study of safety regulations and product standards, with particular reference to their effects on western manufacturers.

In addition to the two-day main conference, special group meetings for manufacturers of lighting equipment, appliances and electrical house heating are being planned for the day and a half preceeding the official opening of the meeting.

Lighting Courses— Fruitful Section/Chapter Activity

Among the most successful and valuable of all local IES programs are the fundamental and advanced lighting courses conducted by numerous Sections and Chapters throughout the country. These courses, often offered in cooperation with the local electric utility companies, attract students who are employees of electrical contractors, distributors, and wholesalers, architect-engineering and consulting engineering firms, fixture manufacturers, utilities and many others. The annual school run by the Florida Section in Tampa, for example, is always assured of a sizeable representation from members of the local electrical apprentice class.

Basic courses are usually conducted in eight sessions covering lighting and seeing requirements, light sources, auxiliary operating equipment and control media, application techniques for industrial, commercial and institutional areas, maintenance and costs. A round-up of present activity indicates that courses are currently being conducted by the Connecticut, Florida, North Texas, Philadelphia and New York Sections.

Advanced lighting courses such as the one underway in Los Angeles, deal with such topics as advanced calculations, glare evaluation, standards of quantity and quality, and lighting problems in relation to acoustics, ceiling suspension systems and the comfortable visual environment.

Power & Light Exhibit Signs Lease For New York World's Fair

A 45,000-square-foot exhibit site at the 1964-1965 New York World's Fair has been leased for the electric utility industry display by Power & Light Exhibit, Inc., administrators of the industry's participation in the Fair. The exhibit will occupy a corner site near a lagoon on two of the Fair's principal traffic arteries.

The power and light exhibit is being planned by VEK Associates, Inc., New York. Principal features are expected to be announced by the middle of the year, according to Ernest R. Acker, president of Power & Light Exhibit, Inc. and chairman of the board of the Central Hudson Gas & Electric Corp.

RLM Standards Institute Adopts New Label

The RLM (Registered Luminaire Manufacturers) Standards Institute, Inc., Meriden, Conn. has announced the adoption of a new label to be used to identify all luminaires manufactured in conformity with the RLM Standard Specifications by companies who maintain membership in the Institute. The new label bears the words "RLM Certified" together with the imprint of the individual manufacturer. As in the past, the label acts as a warrantee from the Institute, the Electrical Testing Laboratories and the manufacturer that the industrial luminaires bearing the label comply with RLM standards and conform to the National Electrical Code.

The RLM Standards Institute has two stated objectives: (1) to establish basic quality standards for materials, construction and lighting performance of industrial units and (2) to simplify the selection of lighting equipment by specifiers, illuminating engineers, electrical engineers, general contractors, plant managers and architects. A catalog of standards specifications is available on request to the Institute, P. O. Box 754, Meriden, Conn.

Reduced Accident Rate Supports Value of Highway Lighting

Lighting for critical sections of highways has proven economically justifiable by the night accidents it prevents, according to recent findings of the Committee on Highway Illumination of the American Road Builders Association. Based on studies conducted in Connecticut, the committee reports that lighting reduced nighttime accidents by 85 per cent on highways and 60 per cent in urban areas.

Results of investigations by the Highway Research Board on traffic accidents in Utah in 1953 and Massachusetts in 1955 indicated that fixed costs for accidents were $5213 for fatal injury, $1277 for non-fatal injury and $299 for property damage. With these amounts now assumed to have risen ten per cent, present day fixed costs can be established as $5734, $1394 and $328, respectively.

By taking local figures for night accident locations, applying the costs listed above to each type of accident and then applying the 85 or 60 per cent prevention percentage, highway officials can deter-

(Continued on page 18A)

Installations in the News . . .

Winter Swimming Thrives Under Heat Lamps

Two rows of heat and sun lamps, 50 lamps per row, installed over the concrete aprons on either side of this pool permit year round swimming and tanning at a Ligonier, Pa. resort. Every eighth bullet-type fixture houses a sun lamp; the other seven are equipped with 250-watt infrared lamps, operated on 10 circuits for flexibility. In one test the heat lamps, which produce 45 watts per square foot of radiant energy, changed the temperature around the pool from 52 to 90 degrees in three minutes. This heating method has greatly improved the economics of heating pool areas, since lamps are turned on only when the pool is in use. During summer months colored floodlights will replace the heat and sun lamps for nighttime drama.

The 20 by 50-foot pool, heated by conventional methods, is housed in a 35- by 67-foot building having two side walls and one end wall of insulated glass, one end wall of concrete block. The pitched roof, supported by steel beams, extends from a height of 9.5 feet at the sides to 16 feet over the center of the pool. Architect for the pool building was Herold Bradley of Pittsburgh. Photo and data courtesy General Electric Co., Cleveland.

(Continued from page 17A)

mine how much roadway lighting can be purchased by accident prevention in their communities.

With these recent results as a background, the Highway Illumination Committee intends to pursue an aggressive information program to further the installation of highway lighting.

W. Warren Booth Retires from G-E Supply Co., Bridgeport

W. Warren Booth retired on April 1 from the position of marketing manager —lighting with the General Electric Supply Co., Bridgeport, Conn., under the company's early retirement program. He was with G-E for more than 34 years.

After graduation from the Georgia School of Technology in 1921, Mr. Booth engaged in architectural work for several years, then in 1924 joined the Carter Electric Co. in Atlanta as a commercial and industrial lighting sales representative. Two years later, Carter became the General Electric Supply Co. In 1932 Mr. Booth was named lighting sales manager for General Electric Supply Co. in Bridgeport, and subsequently was promoted to marketing manager.

His membership in IES dates from 1929 when he joined the Society as an Associate, transferring to Member grade in 1936. Mr. Booth has been his company's official representative to the Society for many years, served on the IES Finance Committee from 1951 to 1957, including a three-year term as chairman; was a member of the National Technical Conference Committee from 1953 to 1956 and a Trustee of the Headquarters Retirement Pension Plan from 1953 to 1956. At present he is active on the Sustaining Membership Committee of which he has been a member since 1957.

ABOUT PEOPLE

Parenthetical designations denote membership grade in the Society.

T. D. Wakefield (A), executive vice-president of the Wakefield Co., Vermilion, Ohio, has been elected president and general manager of the Art Metal Co., Cleveland. Other Wakefield officials named to Art Metal posts include **D. A. Schisler** (A) as vice-president—marketing and **R. M. Brown** (A) as sales manager. New appointments of Art Metal personnel include **E. R. Kiernan** as assistant general manager, **L. I. Dvorak** as production and plant engineer, **A. W. Matteson** (A) as chief engineer and **G. J. Bolles** as field service manager.

Joseph R. Ray has been named vice-president in charge of sales for Curtis-AllBrite Lighting, Inc., Chicago, Ill. Formerly, he served the company as general sales manager.

The appointment of **George E. Watkins** as director of the new Research Division of the Edison Electric Institute has been announced by Edwin Vennard, vice-president and managing director of EEI. Chairman of the new Research Division Executive Committee is **Willis Gale,** chairman of Commonwealth Edison Co., Chicago, Ill. Also announced was the appointment of **Albert V. Lowe** as manager of the Institute's Live Better Electrically program. He succeeds **Ralph Zeuthen,** who has joined Compton Advertising, Inc. as vice-president and account supervisor.

The Bryant Electric Co., Bridgeport, Conn. has named **William R. Felton** as architectural engineer for the New York area, according to an announcement by W. B. Rankin, eastern zone manager. In his new position, Mr. Felton will be responsible for contact with specifying factors in the architectural, engineering and contracting fields.

John C. Virden, Jr., president of the John C. Virden Co., Cleveland, Ohio, has announced the formation of a third divi-

(Continued on page 21A)

"America's finest fluorescent lighting"

Recessed Slendex solves tough ceiling problems . . . in low ceilings . . . in minimum cavities. Recessed only 1⅜" . . . so shallow it handles like tile. Surface-mounted Slendex is only 3" deep overall . . . ideal for low ceiling installations. Simplify your next project with Smithcraft Slendex. One foot wide for two lamps; two feet wide for four lamps.

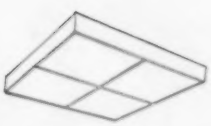
Slendex, as well as all Smithcraft fluorescent lighting equipment, may be leased under the Smithcraft LEASE-LIGHT* Plan to conserve capital while enjoying the benefits of good lighting.

Smithcraft Lighting CHELSEA 50, MASSACHUSETTS

Smithcraft Slendex

*Registered Mark Smithcraft Corporation

SPECIFY SMITHCRAFT UNITS FOR EVERY LIGHTING APPLICATION



OFFICES — Smithcraft **LARGE ELEMENT** Pre-assembled modular units for high-level, comfortable illumination of any area, in any pattern.

SCHOOLS — Smithcraft **CHELSEA** Tops them all for crisp, clean good looks, cool low brightness and fast, easy installation. More fixture for your money!

STORES — Smithcraft **SONOLUME CEILING SYSTEM** High-level illumination, plus effective sound absorption. Just 7" deep — adapts to any ceiling plan.

INDUSTRY — Smithcraft **POWER-GROOVE INDUSTRIAL** Up to 2½ times higher lighting levels at a lower cost per footcandle. PV series provides 25% uplighting.

Efficient methods mean orderly, accurate assembly. Here, overhead conveyor moves luminaires in our spacious plant.

Manufacture of hinged poles — these and other products flow quickly through production system for on-time delivery.

What makes Revere the consultant's choice for outdoor lighting?

Revere builds lighting equipment to outlast even the user's expectations

How long do your clients expect their outdoor lighting equipment to last? *Most* users expect the equipment they invest in to last at least as long as the application. It seldom does. Realistic consulting electrical engineers know that in outdoor lighting, as in most other things, you get exactly what you pay for in terms of engineered light output and in equipment durability.

Revere people know this too. That's why it's company policy to build up to a quality level, never down to a price level. The slight price premium sometimes commanded by Revere products is invested by the factory in manufacturing and design refinements which assure a generous return in terms of premium performance and durability. The result is reliability you don't often see, and added years of service you don't usually expect.

Just as the lighting specifier can select exactly the right equipment for any application from Revere's wide line, so can Revere utilize all the resources of a large, modern plant to select the best manufacturing method for each product. When you specify Revere your clients get all the light they're paying for, delivered where they want it, in fixtures designed and made to outlast even the user's expectations.

Write for your copy of Revere's comprehensive outdoor lighting catalog. Or see your Revere sales engineer for prompt answers to your questions on how our standard line or custom design service can serve your needs.

Revere ELECTRIC MFG. CO.

OUTDOOR LIGHTING

Revere Electric Mfg. Co. • 7420 Lehigh Avenue • Chicago 48, Illinois (In suburban Niles)
Long Distance Phone: NIles 7-6060 • Chicago Phone: SPring 4-1200 • Telegrams: WUX Niles
In Canada: Curtis Lighting, Ltd., Leaside, Toronto, Ontario

Components such as this spun aluminum reflector are carefully fabricated to exceed application requirements.

Electrostatic spray painting produces a smooth, consistent, long-lasting prime coat on Revere poles and sub-assemblies.

An important part of Revere's service is the custom design and production of any special equipment needed for the job.

(*Continued from page 18A*)

sion—Interior Systems, Inc. The new division, with headquarters in the City of Industry, Calif., will be concerned with the manufacture and marketing of interior systems products for commercial, industrial and institutional construction. Paul G. La Vigne, general manager of Virden's western operations, will head Interior Systems.

Frank J. Marriett (M), director of engineering for Thomas Industries, Inc., has announced the appointment of **Wallace T. Rouse** as manager of engineering for the firm's Fort Atkinson, Wis. plant. Mr. Rouse, who will have charge of new product research and development and production line engineering, succeeds Charles J. Stuart, named as manager of the plant.

Arthur H. Landau has joined the industrial management department of ENGINEERS, Inc., Consulting Engineers, Newark, N. J. Formerly, Mr. Landau was associated with the McPhilben Manufacturing Co. as works manager and chief engineer.

The appointment of **Richard J. Caesar** (A) as sales manager has been announced by the Major Equipment Co., Chicago, Ill. Prior to joining Major, Mr. Caesar was affiliated with Corning Glass Works, Corning, N. Y.

The Edwin F. Guth Co., St. Louis, Mo., has announced the appointment of **Glenn H. Arnold** (A) as their manufacturers' agent for Georgia and southern South Carolina.

According to announcements by H. L. Burpo, regional manager of the Union Carbide Plastics Co., a division of the Union Carbide Corp., **William R. Neely** and **Fredric M. Smith** have been appointed as technical representatives in the company's mid-western sales region. Mr. Neely will be located in Kansas City, Mo., and Mr. Smith will make his headquarters in Chicago, Ill.

The appointment of **Manufacturers Sales Agency**, Omaha, Nebr., as representatives in eastern Nebraska and Iowa has been announced by The Kirlin Co., Detroit, Mich.

Deaths

A. W. Morrison, New England Section
D. L. Morse, Chicago Section
A. H. Rogers, New England Section
R. A. Siedle, Rochester Section
R. W. Stanley, Housatonic Chapter

(*News continued on page 22A*)

SCHEDULED EVENTS

1961 Dates of Interest to IES Members

April

April 20-21—Southeastern/South Central Regional Conference, IES, Biltmore Hotel, Atlanta, Ga.

April 23-28—American Institute of Architects, Annual Convention, Philadelphia, Pa.

April 29-May 3—National Association of Electrical Distributors, Annual Convention, Detroit, Mich.

April 30-May 4—Electrochemical Society Meeting, Claypool Hotel, Indianapolis, Ind.

May

May 1-2—Intermountain Regional Conference, IES, Salt Lake City, Utah.

May 1-3—American Institute of Electrical Engineers, Rural Electrification Conference, Kentucky Hotel, Louisville, Ky.

May 2-4—Electric Association of Chicago, Sixth Biennial Midwest Electrical Industry and Lighting Exposition, McCormick Place, Chicago, Ill.

May 4-5—South Pacific Coast Regional Conference, IES, Sacramento Inn, Sacramento, Calif.

May 8-9—Pacific Northwest Regional Conference, IES, Harrison Hot Springs, Harrison, B. C.

May 15-16—Canadian Regional Conference, IES, Queen Elizabeth Hotel, Montreal, Que.

May 15-17—Building Research Institute Conference, Shoreham Hotel, Washington, D. C.

May 22-25—Design Engineering Show, Cobo Hall, Detroit, Mich.

June

June 2-3—Maritime IES Conference, Moncton, N. B.

June 5-7—Edison Electric Institute, Annual Convention, New York, N. Y.

June 5-9—Society of the Plastics Industry, National Conference, Commodore Hotel, New York, N. Y.

June 6-7—IES Council Meeting, Barbizon Plaza Hotel, New York, N. Y. Members are invited to attend meetings as guests of Council.

June 8-9—Northeastern Regional Conference, IES, Berkeley-Carteret Hotel, Asbury Park, N. J.

June 18-23—American Institute of Electrical Engineers, Summer General Meeting, Ithaca, N. Y.

June 19-20—Great Lakes Regional Conference, IES, Sheraton-Gibson Hotel, Cincinnati, Ohio.

June 26-28—American Society of Heating, Refrigerating and Air Conditioning Engineers, Annual Meeting, Denver-Hilton Hotel, Denver, Colo.

July

July 4-7—National Society of Professional Engineers, Annual Meeting, Olympic Hotel, Seattle, Wash.

July 18-20—Western Plant Maintenance Show, Pan Pacific Auditorium, Los Angeles, Calif.

August

August 21-23—National Association of Lighting Maintenance Contractors, National Convention, Flamingo Hotel, Las Vegas, Nev.

September

September 12-15—Industrial Building Exposition, New York City Coliseum, New York, N. Y.

September 14-15—Engineering Management Meeting, sponsored by AIEE and ASME, Hotel Roosevelt, New York, N. Y.

September 24-29—Illuminating Engineering Society, National Technical Conference, Chase-Park Plaza Hotel, St. Louis, Mo.

October

October 4-6—Canadian Electrical Manufacturers Association, Annual Meeting, Sheraton-Brock Hotel, Niagara Falls, Ont.

October 4-6—International Association of Electrical Leagues, Annual Conference, President Hotel, Atlantic City, N. J.

October 9-10—United States National Committee, CIE, Annual Meeting, Olentangy Inn, Columbus, Ohio.

October 10-12—American Standards Association, National Conference on Standards, Rice Hotel, Houston, Texas.

October 10-13—National Electrical Contractors Association, Annual Convention and Exposition, Washington, D. C.

October 15-20—American Institute of Electrical Engineers, Fall General Meeting, Detroit, Mich.

October 18-20—Optical Society of America, Annual Meeting, Biltmore Hotel, Los Angeles, Calif.

Installations in the News . . .

Shopping Center Parking Area

Parking area at the new Crossroad's Shopping Center outside Omaha, Nebr. is lighted by 400-watt improved-color mercury lamps mounted four per pole on 51 poles. The poles rise 30 feet above two-ballast, four-lamp transformers set on two-foot concrete bases.

The lighting operates on a 277-volt system, keeping wiring costs to a minimum. Maintenance is simplified by a special mechanical lowering device for the lamps which is incorporated into the pole design. Photo and data courtesy Valley Mfg. Co., Valley, Nebr.

BOOKS AND PAMPHLETS

Books marked * may be inspected in the Technical Office at Headquarters.

Power and Progress, published by the Edison Electric Institute, 750 Third Ave., New York 17, N. Y. No charge for single copies.

A nontechnical report on electric power production in the United States—its growth and present status as well as its future—is presented in this new 36-page edition of the booklet.

Quantity prices are available.

The Art of Interior Design,* by Victoria Kloss Ball, published by the Macmillan Co., 60 Fifth Ave., New York 11, 1960, 343 pages, illustrated and indexed, $8.50.

The main purpose of this book is stated in its subtitle, "A Text in the Aesthetics of Interior Design." The author, who is an associate professor in the interior design program at Western Reserve University, has placed the emphasis on the design factor in interior decoration. There are chapters on such topics as coordinating the interior design with the structure, understanding and using color, light in interior design, and design and expression. Chapter VI, "Understanding Color," includes: the psychological attributes of color, the color stimulus-light, the visual process and the measurement and specification of color. Chapter VIII, "Light as an Aesthetic Factor in Interior Design," includes: characteristics of light and its measurement, methods of controlling light, requirements of adequate lighting, design through light, design of lighting fixtures, lighting art objects, ways of securing light in interiors, and planning for home lighting.

Colour in Industry Today,* by Robert F. Wilson, published by the Macmillan Co., 60 Fifth Ave., New York 11, N. Y., 1960, 90 pages, illustrated and indexed, $8.00.

This British book, which is subtitled "A Practical Book on the Functional Use of Colour" was written to explain the theory of color and its practical application in all spheres of life. Chapter headings include: The Science of Colour, Colour Vision, The Psychology of Colour, The Uses of Colour, Suggested Colour Schemes, Hospital and Schools, and Lighting in Industry. The chapter on lighting covers the general requirements for effective industrial lighting.

The author, who died before the manuscript was complete, was Art Director of the British Colour Council for 25 years.

Farm Electric Sales Handbook, published by the Farm Group of the Edison Electric Institute, 750 Third Ave., New York 17, N. Y.

Designed for use as a reference by farm electric salesmen and college agricultural extension services, the publication contains general information to enable the salesman to provide his customer with an idea of the various aspects, including approximate cost, of an electric application. In this revised edition, chapters have been added to cover electric motors, electric welding, emergency lighting and water warming for livestock. Statistics pertaining to such considerations as approximate equipment

(Continued on page 24A)

Any Problems with Integration of Lighting/Heating/Air Conditioning?

IE is planning to round up the experts' answers to questions readers may have on this currently urgent subject. Questions should be confined to the technical and application aspects of lighting/heating/cooling and should not refer to the commercial aspects of the problem.

Send your questions, by May 15, to Miss Ruby Redford, Editor, ILLUMINATING ENGINEERING, 1860 Broadway, New York 23, N.Y.

2 out of 3 architects, contractors, distributors say:

"THIS EMBLEM ON A FIXTURE BALLAST MEANS TOP PERFORMANCE!"

CBM CERTIFIED by ETL

Among a nationwide sample of
1200 architects, contractors and distributors
2 out of 3 linked CBM with **top performance.**

CBM Ballasts are checked by tests regularly at E.T.L.

And they're right! For Certified CBM Ballasts must meet rigid standards for performance . . . as checked by independent ETL. And these CBM specifications also provide many practical benefits . . . including • longer ballast life • higher light output, and • up to 2500 hours longer lamp life than with non-certified ballasts. You get UL listing, too! So when you specify or install fluorescent lighting fixtures, it pays to insist on fixtures that have Certified CBM Ballasts. If you'd like to keep posted on ballast facts and news, ask us to send you CBM NEWS.

Write **CERTIFIED BALLAST MANUFACTURERS,** 2116 Keith Bldg., Cleveland 15, Ohio.

2-61

Participation in CBM is open to any manufacturer who wishes to qualify

ON THE CIRCUIT—IES President Richard G. Slauer, shown here with Milwaukee Section Chairman Edwin Schnoll (left in photo above) at the Milwaukee Engineering Societies' joint meeting on February 22 in honor of Engineers' Week, and as a panel member (photo at right) for a seminar on integration of lighting and air conditioning at the Chicago Lighting Institute. Other panel members at the Chicago meeting included, l. to r.: Robert King, Harris Trust & Savings Bank; W. A. Metsch, Jr., Skidmore, Owings & Merrill; Samuel R. Lewis, consulting engineer, all of Chicago; W. S. Fisher, General Electric Co., Cleveland; (Mr. Slauer) C. E. Heimbrodt, Holabird & Root, architects, Chicago. Mr. Slauer's speech on "Light for Living" at the Milwaukee meeting was one of three made in connection with Engineers' Week. Others were at the Twin City and New England Sections.

(Continued from page 22A)

costs, motor sizes and prices, wire selection and silo capacities are also included.

The complete handbook, in the form of a loose-leaf notebook in a binder, is priced at $4.25; the text alone is $2.75, the binder is $1.50. Special prices are available for members of EEI. Orders should be sent to the Sales Division, Edison Electric Institute, at the address noted above.

Roads and Their Traffic*, edited by Ernest Davies, published by Philosophical Library, Inc., 15 East 40th St., New York 16, N. Y., 1960, 352 pages, illustrated and indexed, $12.00.

The object of this British book is to provide an introduction to traffic engineering and to arouse a greater appreciation of its importance. It also aims to describe the many functions of the traffic engineer, including the methods he employs and the techniques he applies and to illustrate these functions with practical examples.

Thirteen authors from several countries have contributed to this book. An 18-page chapter titled "Road Lighting," written by Granville Berry, who is City Engineer and Surveyor, Coventry, England, President of the Association of Public Lighting Engineers (1958-59), and Member of Road Research Board, is included. This chapter deals with such topics as statutory responsibilities for lighting roads, codes of practice, and layout and design of lighting installations. Other chapters deal with safety, research, signs, parking, traffic control and traffic engineering.

Mechanical - Electrical Equipment Handbook for School Buildings,* by Harry Terry, published by John Wiley & Sons, Inc., 440 Fourth Ave., New York 16, N. Y., 1960, 412 pages, illustrated and indexed, $9.50.

This handbook concerns the installation, care and use of mechanical and electrical equipment for school buildings —equipment used in heating and ventilating, plumbing, sewage disposal, kitchens and cafeterias, and illumination and wiring. The author, who has been a consulting engineer for twenty years, feels that the handbook is written in language that can be understood by readers without a technical education.

The section on illumination touches on classroom, auditorium, gymnasium and stage lighting, maintenance of luminaires and on trouble shooting fluorescent units. The present New York State school lighting requirements are shown and the IES current recommended levels of illumination are referred to.

Precision Measurement and Calibration, National Bureau of Standards Handbook 77, in three volumes: Volume I, **Electricity and Electronics,** $6.00; Volume II, **Heat and Mechanics,** $6.75; Volume III, **Optics, Metrology, and Radiation,** $7.00. Available from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.

A compilation of the more important National Bureau of Standards publications dealing with precision measurement and the calibration of standards, the handbook was designed as a quick reference source for workers in the field of standards, and also as a textbook and aid to scientists and engineers in the standards laboratories. Originally issued as circulars, research papers, chapters of books and articles in scientific journals, publications for inclusion in each of the three volumes were chosen on the basis of having, in the past, best served the needs of scientists in specialized fields of measurement.

Volumes may be purchased singly.

NEW MEMBERS

At the meeting of the IES Council in New York City on March 8, 1961, the following were elected to membership. Names marked * are transfers from Associate Member Grade.

CANADIAN REGION

Bluenose Chapter

No Elections

Forest City (London) Chapter

Associate Members:

Mrohs, L. C., Blackwell, Hagarty and Buist, London, Ont.

Stevenson, D. S., Wakefield Lighting, Ltd., London, Ont.

Golden West Chapter

Associate Members:

Cogger, L. B., Dominion Sound Equipment Ltd., Regina, Sask.

Plaxton, L. E., Canadian General Electric, Regina, Sask.

(Continued on page 27A)

Ceiling for the new California Bank main branch in Los Angeles. Interior designer, Henry Dreyfuss. Installed by Harold E. Shugart Co., Los Angeles. Ceiling made from BAKELITE Brand rigid vinyl sheet panels by Cepco, Inc., San Francisco, California.

A Bank Draws High Interest On Its
LONG-TERM INVESTMENT IN LIGHTING

There's a friendly, refreshing note in this Los Angeles bank's brilliant lighting. Glare-free and shadowless, the luminous ceiling is a snowy expanse of translucent BAKELITE rigid vinyl sheets suspended beneath fluorescent fixtures. The huge panels, four feet square, consist of a top and bottom sheet with an air space between and are placed in a metal frame under tension to facilitate handling. For years to come, the ceiling will stay as beautiful as it is. Accelerated aging tests show high resistance to ultra-violet light.

Now . . . high impact resistance! BAKELITE rigid vinyl sheets are now available with *new high impact qualities* that provide extra resistance to hard knocks . . . the wear and tear of installation and maintenance . . . cracking and warping. These sheets are normally unaffected by moisture and detergents, and, because of their light weight, they are easy to install, remove, and maintain.

New designs or renovations can be given a lift with better lighting. Install luminous ceilings made with *high-impact* BAKELITE rigid vinyl sheet. For information, write Dept. IU-72D, Union Carbide Plastics Company, Division of Union Carbide Corporation, 270 Park Avenue, New York 17, N. Y. *In Canada:* Union Carbide Canada Limited, Toronto 12.

BAKELITE and UNION CARBIDE are registered trade marks of Union Carbide Corporation.

UNION CARBIDE

new SOLA indoor mercury-lamp transformer

provides parallel protection

. . . plus constant-wattage stability!

Here's the big improvement you've waited for in *mercury lamp ballasting:* a really stable, *parallel-type*, constant-wattage, *2-lamp* transformer. Even if one lamp burns out, this new SOLA transformer keeps the other shining steadily.

And SOLA's *constant-wattage performance* protects both lamps and wiring against surge current . . . forestalls flicker by providing complete electrical independence between paired lamps; also, automatically compensates for line-power fluctuations. And the modest starting demand of SOLA constant wattage allows you to install more fixtures per circuit without having to step up wire sizes. The cost advantages are obvious in lighting warehouses, docks, sheds, and similar types of installations.

Contact your SOLA representative for details on new 2-lamp indoor constant-wattage MV transformers, as well as the other indoor and outdoor alternative units. Or write for information, mentioning *parallel MV indoor transformer.*

- "Paralleling" ends double lamp-outages
- Exclusive constant-wattage design holds lumen output within ±1% for line-voltage changes as great as ±13%, assuring full-rated lamp life
- Prevents "drop-out" since input voltage must fall 30% below nominal before lamps extinguish
- Inherent protection against open or short-circuited lamps
- UL listed
- Available for 115, 208, 230, 277, 460 and 575-volt input

SOLA

A DIVISION OF BASIC PRODUCTS CORPORATION

BPC

SOLA ELECTRIC CO.
Busse Road at Lunt,
Elk Grove Village, Ill.
HEmpstead 9-2800
IN CANADA, Sola-Basic Products Ltd., 377 Evans Ave., Toronto 18, Ont.

(*Continued from page 24A*)

HAMILTON ONTARIO CHAPTER

Associate Member:
Noyes, J. M., Canadian Westinghouse Co. Ltd., Hamilton, Ont.

MARITIME CHAPTER

No Elections

MONTREAL SECTION

Associate Members:
Boles, P. A., Northern Electric Co. Ltd., Montreal, Que.
Chiarelli, D., Brais, Frigon and Hanley, Montreal, Que.
Foster, P., Dominion Tar and Chemical Co. Ltd., Montreal, Que.
Kobernick, E. D., E. G. Electric Co., Montreal, Que.
Morissette, R., Union Electric Supply Co., Montreal, Que.
Neate, G. R., Dominion Tar and Chemical Co. Ltd., Montreal, Que.

NORTHUMBERLAND CHAPTER

Associate Members:
Carey, J. W., J. Carey & Associates, Moncton, N. B.
Steeves, L. G., 6 Lynch St., Moncton, N. B.
Watson, M. P., The Holden Co. Ltd., Moncton, N. B.

OTTAWA SECTION

Associate Member:
Argun, Z. N. H., Ottawa Technical Services, Ottawa, Ont.

QUEBEC CHAPTER

No Elections

ST. MAURICE VALLEY CHAPTER

No Elections

TORONTO SECTION

Associate Members:
Attenborough, A. E., Ainsworth Electric Co., Rexdale, Ont.
Gonnet, C. E., Proctor & Redfern, Toronto, Ont.
Quigg, J. J., Powerlite Devices Ltd., Toronto, Ont.
Tenbrummeler, Bert, Wakefield Lighting Ltd., Willowdale, Ont.

WINNIPEG CHAPTER

Associate Members:
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Ligertwood, D. A., 741 Lansdowne Ave., Winnipeg, Man.
Wolk, N., 205-583 St. Mary's Road, Winnipeg, Man.
Wong, R. J., Crowther, MacKay & Associates, Winnipeg, Man.

EAST CENTRAL REGION

CAPITAL SECTION

Member:
Farris, O. F., Federal Aviation Agency, Washington, D. C.

Associate Members:
Black, W. R., Virginia Electric and Power Co., Alexandria, Va.
Croom, M. P., 8103 Eastern Ave., Silver Spring, Md.

EASTERN PENNSYLVANIA SECTION

Associate Member:
Michaels, G. J., Pennsylvania Power and Light Co., Hazleton, Pa.

MARYLAND SECTION

Member:
*Ehrlich, S. E., Excello Public Service Corp., Baltimore, Md.

Associate Members:
Bock, E., Egli & Gompf, Inc., Baltimore, Md.
Meyer, C. R., The Potomac Edison Co., Hagerstown, Md.
Parrott, E. B., Dominion Electric Supply Co. of Baltimore, Inc., Baltimore, Md.

PHILADELPHIA SECTION

Associate Members:
Dundon, G. T., 114 Sandra Rd., Fairfax, Wilmington, Del.
Ferguson, T. J., III, Penn Electric Supply Inc., Philadelphia, Pa.
Galemmo, R. A., Conrad F. Bond, Flourtown, Pa.
Morris, F. H., Philadelphia Electric Co., Philadelphia, Pa.
Morrison, R. B., Westinghouse Electric Corp., Philadelphia, Pa.
Schreiner, C. D., Westinghouse Electric Corp., Philadelphia, Pa.
Stevens, D. G., Keystone Electric Manufacturing Co., Philadelphia, Pa.
Herman, J. K. Jr., Thomas J. Malone, Architect, Haddonfield, N. J.

PITTSBURGH SECTION

Associate Members:
Razzano, D. J., Pittsburgh Fluorescent Renualite, Inc., New Castle, Pa.
Zawlocki, K., Sylvania Electric Products Inc., Wheeling, W. Va.

VIRGINIA SECTION

No Elections

Installations in the News . . .

Quartz Lamp Lighting for Golf Course

Report of another lighting installation for a short-hole golf course, a private facility in North Carolina, attests to the growing popularity of this practice, as reported in March IE. This latest installation uses sixty-six 1500-watt quartz incandescent lamps mounted on 12 poles at a height of 30 feet. Lamps are operated at 277 volts.

Lighting levels provided by the system are approximately three footcandles on the greens, seven footcandles on the fairways, with units aimed to reveal golf balls both in flight and on the ground. Floodlighting for a putting green is supplied by two more of the quartz incandescent units.

Photo and data are courtesy of General Electric Co., Nela Park, Cleveland, Ohio.

GREAT LAKES REGION

BUCKEYE CHAPTER

Associate Member:
Claibourne, G., Jr., Columbus and Southern Ohio Electric Co., Hillsboro, Ohio.

CENTRAL NEW YORK SECTION

Associate Member:
Anthony, C. M., Brewer-Titchener Corp., Cortland, N. Y.

CLEVELAND SECTION

Associate Members:
Everly, B. A., Westinghouse Electric Corp., Cleveland, Ohio.
Frisbie, F. R., Jr., The Illuminating Co., Ashtabula, Ohio.
Roehr, L. A., General Electric Co., Cleveland, Ohio.
Traves, R. W., R. W. Traves Co., Cleveland, Ohio.
Zacharias, R. G., McGeorge-Hargett & Hoag, Cleveland, Ohio.

KENTUCKIANA CHAPTER

Associate Member:
Hesse, A. W., Jr., E. R. Ronald and Associates, Louisville, Ky.

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(*Continued from page 27A*)

MIAMI VALLEY SECTION

Associate Members:
Etter, H. W., Milton Electric Co., West Milton, Ohio.
Wehrkamp, K., Schweiger, Heapy and Associates, Dayton, Ohio.

MICHIGAN SECTION

No Elections

NORTHWESTERN OHIO SECTION

Associate Members:
Cook, L. T., Gross Electric Co., Toledo, Ohio.
Desai, S. G., Samborn, Steketee, Otis and Evans, Toledo, Ohio.
McGee, R. R., Samborn, Steketee, Otis and Evans, Toledo, Ohio.
Mick, Francis, Gross Electric Co., Toledo, Ohio.
Vetter, D. C., Bostwick-Braun Co., Toledo, Ohio.

OHIO VALLEY SECTION

Associate Members:
O'Malley, T. K., Westinghouse Electric Corp., Cincinnati, Ohio.
Niesen, J. R., 2838 Lawndale Ave., Cincinnati, Ohio.

ROCHESTER SECTION

Associate Members:
Foreman, A. R., Joseph Foreman Electrical Co. Inc., Rochester, N. Y.
Grainger, D. A., Heinrich-Seibold, Rochester, N. Y.
Tracy, J. J., General Electric Co., Rochester, N. Y.

WESTERN MICHIGAN SECTION

Associate Members:
Dillon, C. R., Electric Equipment and Supply, Muskegan Heights, Mich.
Hopkins, A. D., S. P. Ecclestone & Sons, Inc., Kalamazoo, Mich.
Steketee, S., Holland Electric Supply Co., Holland, Mich.

WESTERN NEW YORK SECTION

No Elections

INTER-MOUNTAIN REGION

ARIZONA SECTION

Associate Member:
Broking, J. L., Arizona Public Service Co., Douglas, Ariz.

NEW MEXICO CHAPTER

Associate Member:
Bennett, C. H., 3509 Mountain, El Paso, Texas.

ROCKY MOUNTAIN SECTION

No Elections

SOUTHERN COLORADO CHAPTER

No Elections

UTAH SECTION

Associate Members:
Evans, G. S., Utah Power and Light Co., Salt Lake City, Utah.
Newmeyer, R. A., Sperry Utah Engineering Lab., Salt Lake City, Utah.

MIDWEST REGION

CENTRAL KANSAS CHAPTER

No Elections

CORNHUSKER SECTION

No Elections

HEART OF AMERICA SECTION

No Elections

ILLINI CHAPTER

No Elections

IOWA SECTION

Associate Member:
Frizell, G. H., Iowa Power and Light Co., Des Moines, Ia.

OZARK CHAPTER

Member:
*Paula, George, Rocketdyne, Neosho, Mo.

ST. LOUIS SECTION

No Elections

NORTH CENTRAL REGION

CENTRAL ILLINOIS CHAPTER

Associate Members:
Carter, L. D., Kiefer Electric Supply Co., Peoria, Ill.
St. John, Jean, Graybar Electric Co., Peoria, Ill.
Tangman, A. E., Oberlander Electric, Peoria, Ill.

CHICAGO SECTION

Associate Members:
Adra, T. B., Appleton Electric Co., Chicago, Ill.
Daily, R. H., Illinois Lighting Associates Inc., Chicago, Ill.
Dwyer, J. P., Efengee Electrical Supply Co., Oaklawn, Ill.
Ensign, W. A., General Electric Co., Chicago, Ill.
Lindell, C. H., Appleton Electric Co., Chicago, Ill.
Marko, M. C., Gilbert A. Johnson, Architect, Rockford, Ill.
Raffaele, C. W., Appleton Electric Co., Chicago, Ill.
Steinke, Earl, Lighting Products Inc., Highland Park, Ill.
Wasilewski, A. J., J. P. Bazzoni and Associates, Chicago, Ill.
Zimmerman, W., Zimmerman Electric, Rockford, Ill.
Cohan, T. R., Abbey Electric Co., Chicago, Ill.

INDIANA SECTION

Associate Members:
Garvin, L. J., Public Service Co. of Indiana Inc., Terre Haute, Ind.
Lunsford, N., Jr., Public Service Co. of Indiana Inc., Connersville, Ind.
Pitman, W. S., Jr., Wholesale Electric Service Co., Kokomo, Ind.
Robold, J. C., Public Service Co. of Indiana Inc., Vincennes, Ind.
Short, R. B., Public Service Co. of Indiana Inc., Kokomo, Ind.

MILWAUKEE SECTION

Associate Members:
Drake, J. G., Westinghouse Electric Supply Co., Milwaukee, Wis.
Feldner, J. E., Trester Engineering Co., Milwaukee, Wis.
Mayer, W. J., Rowland Associates, Bancroft, Wis.

TWIN CITY SECTION

Associate Members:
Bartl, W. T., Gombold Electric Inc., St. Paul, Minn.
Kent, J. W., Northern States Power Co., Mankato, Minn.
Peterson, A. F., Roger-Douglas Sales Co., Hudson, Wis.

TWIN PORTS CHAPTER

Associate Members:
Nelson, D. W., Graybar Electric Co., Duluth, Minn.
Poupore, N. W., Minnesota Power and Light Co., Duluth, Minn.

NORTHEASTERN REGION

CONNECTICUT SECTION

Associate Members:
Egan, E. F., The Miller Co., Meriden, Conn.
Janowiec, R. P. Bemis & Freeman, Consulting Engineers, Hartford, Conn.
McArdle, E. J., Anemostat Corp. of America, Hartford, Conn.
Nolin, R. B., 332 Elmwood Drive, Meriden, Conn.
Senofonte, J. L., The American Electric Supply Co., Hartford, Conn.

EASTERN NEW YORK SECTION

Associate Member:
Archibald, L. D., Jr., Niagara Mohawk Power Corp., Schenectady, N. Y.

HOUSATONIC CHAPTER

Associate Member:
Smith, H. K., Yale University, School of Drama, New Haven, Conn.

NEW ENGLAND SECTION

Member:
*Lamson, P. H., Wheeler Reflector Co., Hanson, Mass.
Associate Members:
Davidson, H., ABC Electric Co., Boston, Mass.

(*Continued on page 49A*)

IES National Technical Conferences

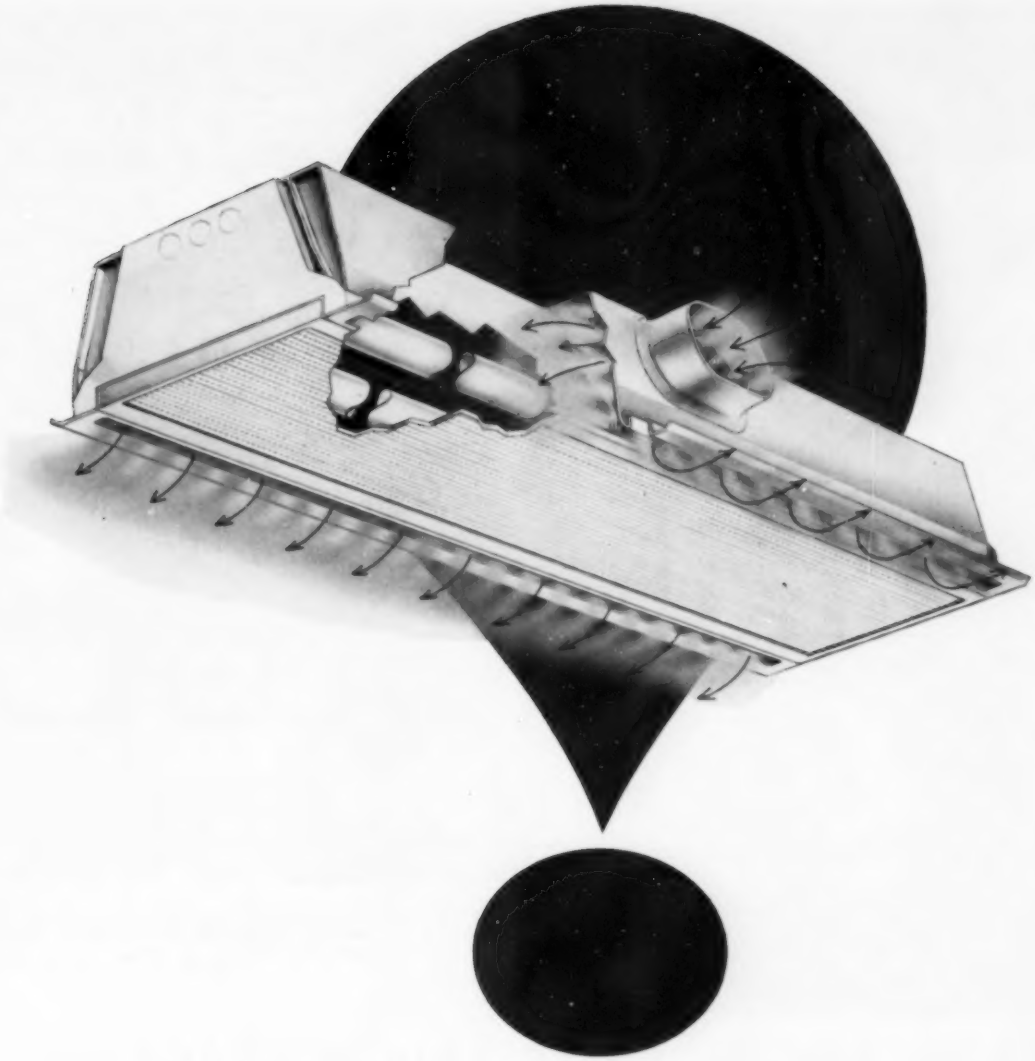
1961—September 24-29—Chase Park Plaza Hotel, St. Louis, Missouri

1962—September 9-14—Statler-Hilton Hotel, Dallas, Texas

1963—September 8-13—Sheraton-Cadillac Hotel, Detroit, Michigan

1964—August 30-September 3—Fontainebleau Hotel, Miami Beach, Florida

1965— Americana Hotel, New York, N. Y.



The fixture that leads 4 lives...

VENTRO-LUX

it provides light • heat • cooling • ventilation

As part of a 10 year product development plan, Curtis AllBrite presents a new fixture, the Ventro-Lux with Anemostat air-diffuser. Four essential services are provided in this combined unit—excellent diffusion of light plus the optimum in heating, cooling and ventilation. The exclusive CALux lens provides effective concealment of lamps, high light output plus attractive appearance. The separate Anemostat air-diffuser handles a high capacity of air which it diffuses horizontally along the ceiling. Result—draft-free distribution, no hot or cold spots, no ceiling smudge. The Ventro-Lux is the first troffer to be combined with a high capacity air-diffuser. Since the Ventro-Lux and Anemostat units are installed separately there is no conflict in the trades. Curtis AllBrite Lighting, Inc., 6135 W. 65th St., Chicago 38, Ill.—352 Shaw Road, South San Francisco, Calif.—Toronto, Canada—Vancouver, B. C., Canada.

CURTIS-ALLBRITE
LIGHTING, INC.
Visioneers in Planned Lighting

new "ceiling of light" from SMOOT-HOLMAN

In the recent modernization of their Ontario, California office, the So. Calif. Edison Company used customized louvered Smoot-Holman "Perfect Vision"® luminaires. These replaced continuous rows of surface mounted, direct fluorescent units.

HERE'S WHY SO. CALIF. EDISON CHOSE "PVs"

● **REMODELING COSTS GREATLY REDUCED – NO NEW CEILING REQUIRED.** This customized "Perfect Vision"® installation, which embodies the use of plastic louvers between the luminous panels, is itself a "ceiling of light." There was no need to rebuild or to drop the ceiling. In the photograph above, the fixtures are suspended from the original ceiling using 18" stem hangers. (This attractive, easy to install and maintain lighting system is also ideal when it is necessary to cover an uneven ceiling, water pipes, beams, or discolorations.)

● **IMPROVED LIGHTING.** Customized louvered Smoot-Holman "Perfect Vision"® luminaires provide comfortable, shadowless illumination. A light level of approximately 150 foot candles is maintained in the office pictured. This installation made a marked improvement in light provided for typing and tasks performed in a vertical plane.

● **EASY TO MAINTAIN.** In contrast to most luminous ceilings, this installation has lamps at the ceiling line for easy cleaning and relamping.

● **BALLASTS LAST LONGER.** Ballast overheating had been a problem with the former surface mounted fixtures. These new suspended fixtures assure cool ballast operation.

● **PLEASING APPEARANCE.** The soft, even lighting – completely without glare – is pleasing to the eye and conducive to good work. The plastic louvers spaced between the "PV" lamp panels give unobtrusive relief from the monotony of a conventional type luminous ceiling.

● **CREDITS.** Mr. James Howard of the So. Calif. Edison Engineering Department, together with Don Rawlinson, lighting consultant in the Ontario office, planned the installation. In Mr. Howard's words, "Without having to rebuild the ceiling, we got improved lighting and a pleasing decorative appearance using customized louvered Perfect Vision® Luminaires."

Write for detailed information

SMOOT-HOLMAN *Company* *Inglewood, California*
ESTABLISHED 1915

COMMITTEE PERSONNEL

COMMITTEES 1960-1961

All committees are appointed by the President, subject to approval of the Council. Except as provided in the Constitution, appointments terminate at the time of the first Council meeting of the following administration. The scope of each committee is indicated.

R. G. Slauer, President, ex-officio member of all Standing, General and Task Committees except Board of Fellows, Board of Nomination and Medal Award Committee.

J. R. Chambers, Vice-President, ex-officio member of all Technical Committees (by appointment).

STANDING COMMITTEES

COUNCIL EXECUTIVE—To conduct the affairs of the Society between Council meetings.

R. G. Slauer, Chairman, Sylvania Electric Products Inc., One 48th St., Wheeling, W. Va.

J. R. Chambers	W. P. Lowell, Jr.
G. F. Dean	J. D. Mitchell

BOARD OF FELLOWS—To evaluate the eligibility of candidates for transfer to the grade of Fellow, according to procedures approved by Council.

Bruce J. Jensen, Chairman, Public Service Electric & Gas Co., 80 Park Pl., Newark, N. J.

L. E. Barbrow	W. E. Folsom
J. W. Bateman	C. H. Rex

George P. Wakefield

FINANCE—To have direct supervision of the financial affairs of the Society and to present to the Council an annual report on its financial condition. To make recommendations to the Council as to the investment of monies and upon all specific appropriations. To prepare and submit for approval of Council not later than the first new Council meeting a budget of income and expense for the ensuing fiscal year.

A. C. Barr, Chairman, General Electric Co., Nela Park, Cleveland 12, Ohio.

H. S. Beagle	C. C. Shotwell
Max D. Orr	R. M. Zabel

W. P. Lowell, Jr., Treasurer, ex-officio

GENERAL BOARD OF EXAMINERS—To investigate the qualifications of all applicants for admission to membership; to elect or reject applicants for the grade of Associate Member and Student Member, to report such action to the Council; and to make recommendations to the Council regarding applications for transfer or election to the grade of Member or Retired Member, and for transfer to the grade of Member Emeritus.

Taylor Barr, Chairman, Central Hudson Gas & Electric Corp., 47 Cannon St., Poughkeepsie, N. Y.

Svend W. Bruun	Clarence W. Clarkson

PAPERS—To procure, review and approve all technical papers and discussions thereof, for presentation before National Conference of the Society.

B. S. Benson, Jr., Chairman, Benjamin Division, Thomas Industries, Inc., Des Plaines, Ill.

F. C. Breckenridge	J. S. Hamel
James Cox	Leon T. Johnson
C. M. Cutler	Roy A. Palmer
H. F. Davidson	T. C. Sargent
Kurt Franck	Floyd W. Sell
O. B. Goldsmith	G. A. Trosper
J. William Griffith	George Wakefield

PUBLICATIONS—To be responsible for the procurement, review and approval of all material for the publications of the Society other than technical papers approved by the Papers Committee for presentation at National Conferences of the Society and their discussions and committee reports, for which it will have publication responsibility only. Shall also be responsible for the editing, printing and business management of the publications of the Society; specific exceptions may be made by Council.

R. W. Morris, Chairman, General Electric Co., Nela Park, Cleveland 12, Ohio.

C. L. Amick	Brooks Chassaing
B. S. Benson, Jr.	George W. Clark

Arthur R. Jaeger

Lighting Data Sheets

Charles L. Amick, Chairman, Day-Brite Lighting, Inc., P.O. Box 141, St. Louis 66, Mo.

Berlon C. Cooper	Vernon T. Kempf

S. D. Snook, Jr.

Residential Lighting Data Sheets

Elizabeth A. Meehan, Chairman, Philadelphia Electric Co., 211 S. Broad St., Philadelphia, Pa.

GENERAL COMMITTEES

ADVANCE PLANNING—To study the long range objectives of the Society—its operation, program, publication activities, membership classifications and financial structure, and to make recommendations to Council.

C. W. McCormick, Chairman, Connecticut Light & Power Co., P. O. Box 2010, Hartford, Conn.

J. M. Chorlton	B. Travis
J. J. Neidhart	L. C. Twichell

J. D. Whitnell

ALLIED ARTS—To encourage and assist local competitions in allied arts, in cooperation with technical committees and interested local groups.

R. W. Brown, Chairman, Cincinnati Gas & Electric Co., Cincinnati, Ohio.

Carl Albach	W. M. C. Lam
Marion G. Currie	Edward Rambusch
Roy Dahlin	Wilbur D. Riddle
C. D. Gill	Joel E. Rubin
W. A. Hedrich	John A. Russell
George F. Herold	J. D. Whitnell

APPLIED LIGHTING COMPETITION—To encourage and assist local and regional competitions and to conduct the national competition during the National Technical Conference, in accordance with procedure approved by the Council.

J. C. Wilson, Chairman, J. A. Wilson Lighting & Display Ltd., 280 Lakeshore Rd., Toronto, Ont.

Raymond L. Smart, Vice-Chairman, Boston Edison Co., 39 Boylston St., Boston 12, Mass.

Jack Cottingham	Carman Miller
G. F. Dean	Allan D. Montgomery
Lloyd Durfee, Jr.	Harry Nellis
Edna Fortier	Joseph Thomas

Carlton Whitworth

BOARD OF NOMINATION—To prepare a nomination ticket containing the names of those who are deemed best suited to serve as officers and directors in positions to be filled at the ensuing election.

K. M. Reid, Chairman, General Electric Co., Nela Park, Cleveland 12, Ohio.

J. B. Browder	G. J. Taylor

and regional representatives

CONSTITUTION AND PROCEDURES — To prepare proposed amendments to the Constitution and By-laws, to prepare statements of policies and procedures consistent with the Constitution and By-laws, and to report to Council.

L. C. Twichell, Chairman, Rochester Gas & Electric Corp., 89 East Ave., Rochester, N. Y.

G. F. Dean	Raymond L. Smart
R. F. Hartenstein	Walter Sturrock
C. C. Keller	Joseph Thomas

HISTORICAL—To assemble and make available for current reference and to prepare in suitable and durable form for posterity, such historical facts, printed memorabilia, photographs, voice records, museum specimens and allied items as may be judged worthy of composing a continuing digest of the record of the Society's history.

Robert L. Zahour, Chairman, Westinghouse Electric Corp., Bloomfield, N. J.

MEDAL AWARD—To evaluate the eligibility of candidates for award of the IES Medal according to procedures approved by the Council.

A. F. Wakefield, Chairman, The Wakefield Co., Vermilion, Ohio.

J. W. Barker	Edward Rambusch
J. B. Browder	K. M. Reid
Wilton B. Hastings	G. E. Shoemaker
W. P. Little	G. J. Taylor

MEMBERSHIP—To develop plans and supervise the operation of the individual membership activity of the Society.

George W. Clark, Chairman, Sylvania Electric Products Inc., One 48th St., Wheeling, W. Va.

A. C. Brodeur	J. M. Gensburger

Robert M. Taylor

(*Continued on page* 32A)

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Regional Representatives

J. Chrismer — L. L. Nurnberger
Roy E. Dahlin — J. S. Ragland
George R. F. Geddie — Joseph Thomas
F. Yanaros

NATIONAL TECHNICAL CONFERENCE — To be completely responsible, subject to the approval of Council, for the general coordination of all conference activities, for selecting and recommending time and place, for review of the plans and budgets of the National Technical Conference Executive Committee, and in cooperation with the Papers Committee for the satisfactory time allocation for the technical papers sessions, according to Procedures and Policies as adopted by Council.

C. L. Amick, Chairman, Day-Brite Lighting, Inc., P. O. Box 141, St. Louis, Mo.

Brooks Chassaing, Vice-Chairman, Chassaing Brothers Lighting, 7603 Forsythe Blvd., St. Louis, Mo.

A. C. Barr — E. T. Dorsey
B. S. Benson, Jr. — P. M. Rutherford
Henry G. Clum — Julian J. Smith
Richard Cohen — L. E. Tayler
John B. Deck, Jr. — J. C. Wilson
Frank Yanaros

1961 Conference Executive Committee

Brooks Chassaing, Chairman, Chassaing Bros. Lighting, 7601 Forsyth Blvd., Clayton 5, Mo.

Frank Cline — Carter Lewis
R. D. Cohen — H. J. Poehling
Edwin H. Lauth — E. W. Stohlmann

PUBLIC RELATIONS AND INFORMATION—To prepare and disseminate information about the activities, accomplishments, programs, objectives and policies of the Society and about the place of illuminating engineering in modern society; to formulate and submit public relations policies and plans to the Society.

Gordon Wells, Chairman, Day-Brite Lighting, Inc., 5411 Bulwer Ave., St. Louis 7, Mo.

J. R. Bailey — Vernon T. Kempf
Richard E. Hars — R. W. Sclater

REGIONAL ACTIVITIES—To represent the respective Regions before the Council and to keep the Council informed regarding the affairs of the Regions. To stimulate Society activities, to encourage joint meetings of Sections and Chapters including Regional Conferences within the respective Regions, and to promote the expansion of the Society.

G. F. Dean, Chairman, Toronto Hydro-Electric System, 14 Carlton St., Toronto, Ont.

Cecil L. Cannon — C. D. Miller
J. M. Chorlton — L. S. Reed
R. D. Cohen — Alston Rodgers
J. T. Cottingham — Richard M. Smart
J. B. Deck, Jr. — J. S. Williams
R. H. Kreyser — R. L. Zahour

RESIDENCE LIGHTING FORUMS—To stimulate and assist the Residence Lighting Forums of the Society and to encourage the formation of additional forums. To conduct a Residence Lighting Forum in connection with the National Technical Conference.

Aileen Page, Chairman, General Electric Co., Nela Park, Cleveland 12, Ohio.

Dorothy Davis — Lloyd Gabler
Myrtle Fahsbender — Jack Sahlman
Frank Feagans — Virginia Skinner
Jack Thompson

SUSTAINING MEMBERSHIP — To develop plans and supervise the operation of the Sustaining Membership activity in the Society according to the Procedures and Policies adopted by Council.

G. J. Taylor, Chairman, Day-Brite Lighting, Inc., 212 South Central Ave., Clayton 5, Mo.

B. F. Benning, Vice-Chairman, Graybar Electric Co., Inc., 420 Lexington Ave., New York, N. Y.

W. M. Baldwin — E. C. Huerkamp
E. D. Bartley — J. J. McLaughlin
W. W. Booth — R. L. Sawyier, Jr.
E. H. Church — C. C. Shotwell
L. E. Tayler

Fund Subcommittee

G. J. Taylor, Chairman, Day-Brite Lighting, Inc., 212 South Central Ave., Clayton 5, Mo.

W. M. Baldwin — W. E. Henges
E. H. Church — J. J. McLaughlin
E. O. George — J. C. Wilson

TRUSTEES, IES HEADQUARTERS RETIREMENT PENSION PLAN

G. J. Taylor, Chairman, Day-Brite Lighting, Inc., 212 South Central Ave., Clayton 5, Mo.

A. C. Barr — J. B. Browder
W. P. Lowell, Jr.

TASK COMMITTEES

STUDY OF LIGHTING SERVICE COMMITTEE—To study and report upon a broader program through which to achieve the committee's objectives to stimulate and promote the discussion and practical applications of lighting recommendations.

W. P. Graham, Chairman, Philadelphia Electric Co., 211 S. Broad St., Philadelphia 5, Pa.

G. J. Gillen — G. J. Kennedy
B. J. Jensen — M. N. Waterman

IES TERRITORIAL AND ORGANIZATIONAL—To study regional boundaries with respect to the preparation of a plan to encompass the future growth pattern of the Society.

J. R. Chambers, Chairman, Appleton Electric Co., 1701-59 Wellington Ave., Chicago 13, Ill.

Brooks Chassaing — C. W. McCormick
J. M. Chorlton — C. D. Miller
G. F. Dean — J. D. Mitchell
M. N. Waterman

FOR FEASIBILITY OF DESIGN CERTIFICATION—To make a study of the feasibility of the IES entering into a program of design certification of all types of luminaires.

J. B. Browder, Chairman, Georgia Power Co., 75 Marietta St., N.W., Atlanta 1, Georgia.

H. S. Beagle — W. C. Brown
R. B. Brown, Jr. — Ward Harrison

ON EDUCATIONAL AND PROFESSIONAL STANDARDS—To study the trend in educational and professional standards for illuminating engineering (including methods for achieving these), consulting with related committees (Education, Membership, Advance Planning), and to prepare recommendations for report to Council.

C. L. Amick, Chairman, Day Brite Lighting Inc., P.O. Box 141, St. Louis 66, Mo.

O. P. Cleaver — T. C. Sargent
K. M. Reid — H. M. Sharp

TECHNICAL COMMITTEES

AVIATION—To study the application of light and lighting to the spaces and functions involved in the operation of aircraft.

C. A. Douglas, Chairman, National Bureau of Standards, Washington 25, D. C.

C. E. Leberknight, Vice-Chairman, Kopp Glass, Inc., Swissvale, Pittsburgh 18, Pa.

John P. Hoxie, Recording Secretary (Program Coordinator), Product Engineering Dept., Corning Glass Works, Corning, N. Y.

Victor Converso, Corresponding Secretary, Aviation Planning Division, Port of N. Y. Authority, 111 8th Ave., New York, N. Y.

Louis Achitoff — **J. G. Hoffman
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P. B. Clark — D. C. Miller
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*C. N. Cook — *J. L. Newton
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*B. Hemelt — A. B. Winters
W. E. Woodson

*Advisory members
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Taxiway Lighting

Lawrence W. Hornfeck, Chairman, 711 Penn Ave. Bldg., Pittsburgh, Pa.

Louis Achitoff — B. Hemelt
C. N. Cook — Ross Knight
James Furr — C. B. Phillips
H. G. Gatlin — J. W. Simeroth

COLOR—To study, evaluate and report on the effect of color in relation to the art and science of illumination.

R. C. Allison, Chairman, The T. Eaton Co., Ltd., 190 Yonge St., Toronto 1, Ont.

W. E. Carswell — G. F. Dean

DAYLIGHTING—To study the problems involved in daylighting, develop recommended practices and report thereon.

J. W. Griffith, Chairman, Southern Methodist University, Industrial Engineering Dept., Dallas, Texas.

(*Continued on page* 34A)

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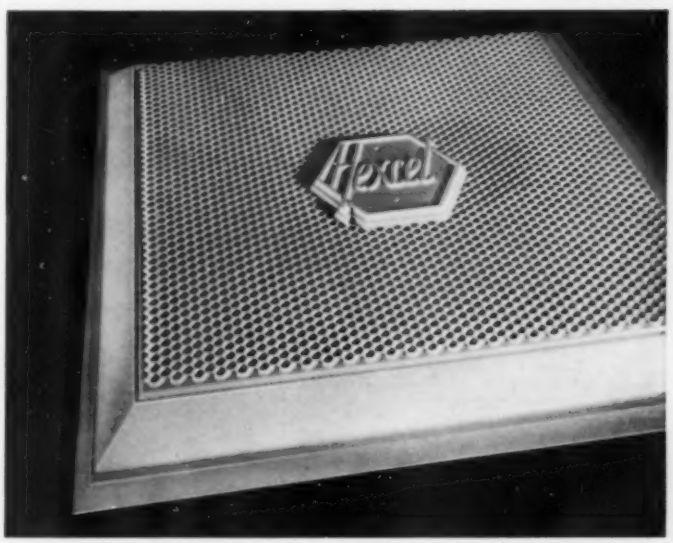

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(*Continued from page* 32A)

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R. A. Boyd — E. M. Linforth
A. A. Brainerd — R. W. McKinley
H. S. Bull — F. W. Mowrey
B. H. Evans — Philip O'Brien
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B. F. Greene — D. E. Spencer
J. J. Kemendo — K. C. Welch
R. C. Kendall — O. F. Wenzler
M. W. Keyes — C. J. Youngblood

DESIGN PRACTICE—To study published data on coefficients of utilization, room indexes, maintenance coefficients and other elements entering into calculations for lighting design; develop standard methods for use in Society publications and report thereon.

Bill F. Jones, Chairman, Smoot-Holman Co., Box 4097, Inglewood, Calif.

Lloyd Durfee — Phelps Meaker
Ward Harrison — J. J. Neidhart
Richard LeVere — R. S. Wiseman

EDUCATION—To study and encourage lighting education and training for professional careers in schools, colleges and elsewhere; to prepare educational and training material on fundamental and advanced concepts of light and illumination, and to further its adoption in courses conducted by Sections and Chapters.

Alston Rodgers, Chairman, General Electric Co., Nela Park, Cleveland 12, Ohio.

Paul H. Hildebrand, Vice-Chairman, Pennsylvania Power and Light Co., Allentown, Pa.

O. P. Cleaver — Roy A. Palmer
Marion G. Currie — R. C. Putnam
E. L. Fairchild — T. H. Shepherd
D. M. Finch — W. Sturrock
W. A. Hedrich — R. S. Wiseman
H. W. Horn — I. A. Yost

Brochure on "Opportunities in Illuminating Engineering"

J. L. Tugman, Chairman, General Electric Co., Nela Park, Cleveland, Ohio.

R. C. Putnam — R. S. Wiseman

Revision of IES Courses

C. W. Zerseu, Coordinator, Chicago Lighting Institute, 140 S. Dearborn St., Chicago, Ill.

Revision of "Lighting Fundamentals Course"

R. E. Wozniak, Chairman, Chicago Lighting Institute, 140 S. Dearborn St., Chicago, Ill.

Robert Allen — B. F. Avery
A. M. Bacalar

Revision of "Advanced Lighting Design Problems Course"

R. R. Lusk, Chairman, Commonwealth Edison Co., 7601 S. Lawndale Ave., Chicago 29, Ill.

Gerald Marks — J. F. Parsons
William Weibel

Science Textbook Review—To work with the Better Light Better Sight Bureau in providing an authoritative review service to assist authors and editors preparing new textbooks or revising existing ones, to insure that text and illustrations on light and lighting are technically correct and up to date. The BLBS Bureau will contact the publishers of science textbooks for use in elementary and secondary schools, obtain the material to be reviewed and act as liaison with this subcommittee, who will do the actual work of review and comment.

J. L. Tugman, Chairman, General Electric Co., Nela Park, Cleveland 12, Ohio.

E. L. Fairchild — P. H. Hildebrand
W. A. Hedrich — J. F. Parsons

HANDBOOK—To have continuous responsibility for appraising the service rendered by the Handbook, for its accuracy and improvement; to advise Council when revisions and new editions are needed. To revise and arrange the technical content of the Handbook; to lay out, plan, and arrange for development of individual sections primarily through appropriate technical committees, to consult with the Publications Committee on its presentation of a suitable publication budget for Council approval; to be responsible to Council for the format, accuracy, and treatment of material.

M. N. Waterman, Chairman, Westinghouse Electric Corp., Bloomfield, N. J.

B. J. Jensen — J. J. Neidhart

INDUSTRIAL—To initiate, follow up and coordinate lighting study projects in the industrial field, review the reports of the various subcommittees in this field and make recommendations to Council.

L. G. Parks, Chairman, Ebasco Services, Inc., 2 Rector St., New York, N. Y.

Theodore Ake — N. T. Kridel
A. A. Brainerd — E. A. Linsday
M. M. Buzan — Howard Long
H. A. Cook — B. J. Monaghan
W. H. Kahler — D. J. O'Neill
D. W. Rowten

Men's Clothing Manufacturing

N. T. Kridel, Chairman, Rochester Gas & Electric Co., 89 East Ave., Rochester 4, N.Y.

L. Gauthier — L. C. Twichell*
W. E. Hayes — C. Uthe
*Advisory

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James Rodisch, Chairman, Philadelphia Electric Co., 211 S. Broad St., Philadelphia, Pa.

Outdoor Production Areas

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D. R. Brown — D. J. O'Neill
William Coffey — W. R. Preece, Jr.
R. E. Faucett — G. L. Sealy
Fred Snider

Recommended Practice

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M. B. Bunson — E. A. Linsday
W. C. Cummings, Jr. — H. W. Mumford
W. H. Kahler — W. S. Till
P. E. King — H. W. Wenson

Rubber Industry

Keith Nesbitt, Chairman, Sacks Electrical Supply Co., Akron, Ohio.

James Bishop, Secretary, Sylvania Electric Products Inc., 4848 W. 130th St., Cleveland 35, Ohio.

L. O. Banahan — Arnold Federman
W. A. Bebb — E. L. Smith

INSTITUTIONS—To initiate, follow up and coordinate lighting study projects in the field of public buildings and private institutions, review the reports of the various study subcommittees in this field and make recommendations to Council.

R. D. Bradley, Chairman, Day-Brite Lighting, Inc., 5411 Bulwer Ave., St. Louis, Mo.

B. F. Avery — C. N. Laupp
L. V. James — J. H. McCulloch
H. M. Sharp

Churches

George Shoemaker, Chairman, Philadelphia Electric Co., 211 S. Broad St., Philadelphia 5, Pa.

John Adams — T. N. Mansell
A. L. Bleecker — H. W. Olsen
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Hospitals

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L. J. Buttolph — H. L. Logan
Rose M. Coakley — R. C. Putnam
Howard Haynes — P. W. Seagers
H. M. Sharp

JOINT FARM (IES-American Society of Agricultural Engineers)—To study the application of light and lighting of farm buildings, surrounding work areas and other rural locations and to report thereon.

Morris Lloyd, Chairman, Niagara Mohawk Power Corp., 535 Washington St., Buffalo 3, N. Y.

J. P. Ditchman — M. O. Whithed
J. P. Schaenzer — D. E. Wiant

JOINT LIGHTING SURVEY—(IES-U.S. Public Health Service)—To outline a method of making a survey of the visual factors of the working environment and the worker's vision and evaluating the findings in terms of visual comfort and effectiveness and eye health.

J. F. Parsons, Chairman, Niagara Mohawk Power Corp., 535 Washington St., Buffalo 3, N. Y.

H. N. Doyle, Vice-Chairman, U. S. Public Health Service, Washington 25, D. C.

Tula Brocard — L. E. Duval, Jr.
L. J. Cahill — A. L. Koven
George Clayton — R. P. Teele

LIGHT CONTROL AND EQUIPMENT DESIGN—Collect and correlate the knowledge and data on means and methods of controlling, directing, reflecting, transmitting and diffusing light and on the principles and practices of equipment design.

J. N. Robertson, Chairman, Los Angeles Dept. of Water and Power, Design and Construction Division, 405 S. Hill St., Los Angeles, Calif.

Milton Buzan, Vice-Chairman, Day-Brite Lighting, Inc., 5411 Bulwer Ave., St. Louis, Mo.

R. S. Hawes, Secretary, K-S-H Plastics, Inc., High Ridge, Mo.

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IES-SPI-NEMA

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W. J. Fitzgerald — Elmer Szantay
George Gilleard — R. D. Ullrich
R. S. Hawes, III — J. H. Versteeg
R. F. Hibbert — George Wakefield
H. A. Williams

LIGHT SOURCES—To correlate and report available information as to the physics of light and light production and the characteristics of current light sources.

Herbert A. Anderson, Chairman, Duro-Test Corp., North Bergen, N. J.

E. F. Kelly, Vice-Chairman, Champion Lamp Works, 330 Lynnway, Lynn, Mass.

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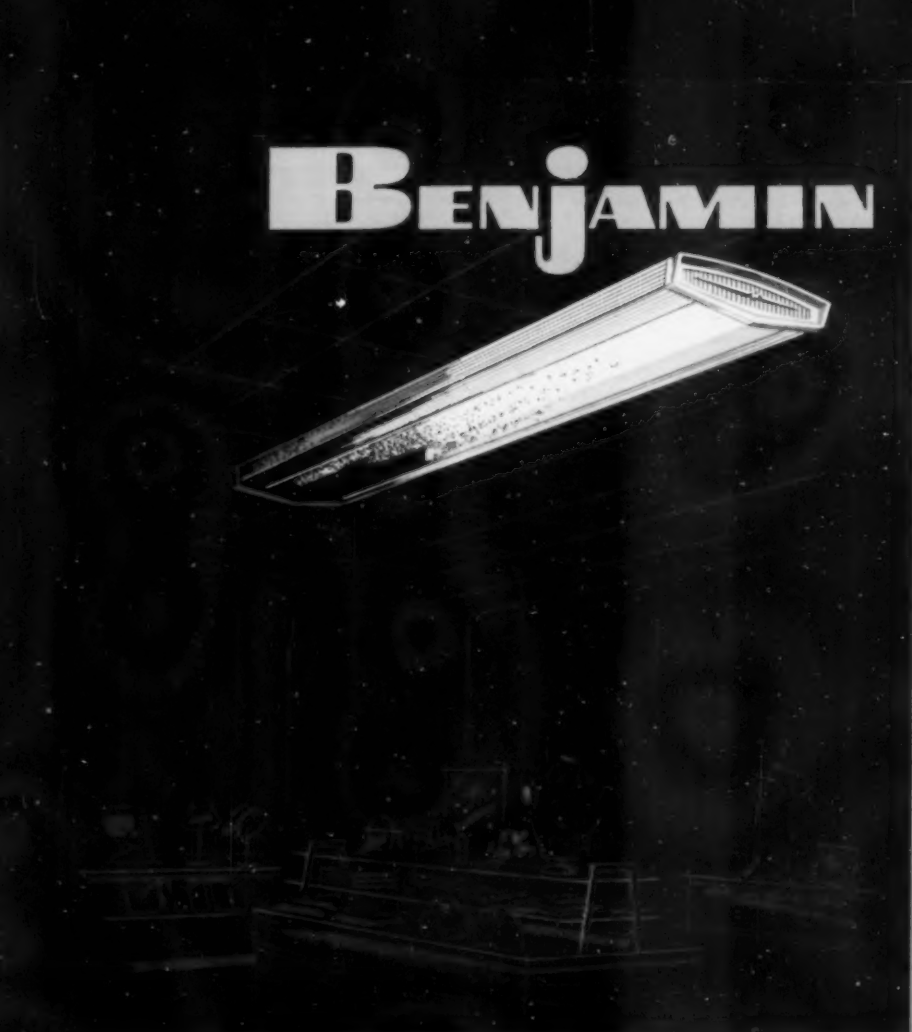
George Freeman — G. R. Stillwell
C. W. Jerome — Luke Thorington
D. B. Judd — A. W. Weeks
Gunter Wyszecki

LIGHTING AND AIR CONDITIONING—To study the relationship between lighting and air conditioning, both with regard to integration of luminaires or lighting systems with heating and cooling requirements, and to their mutual effects on room environment.

(*Continued on page* 36A)



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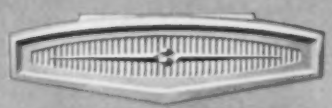
No visible metal supports. Can be mounted singly or in continuous unbroken line. Variety of light-diffusing lenses for any purpose. Two or four lamp. Forty-eight inch lengths.



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H. T. Yopp

MAINTENANCE—To study the elements contributing to maintenance factors; set up the framework of typical field studies to determine factors; and to stimulate the prosecution of such studies by appropriate agencies.

Leo Duval, Chairman, Sylvania Electric Products Inc., 60 Boston St., Salem, Mass.

V. W. Diak

MERCHANDISING (formerly Store Committee)—To study the application of light and lighting to the spaces and processes involved in the selling of goods and to report thereon.

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MOTOR VEHICLE (EXTERIOR)—To study the problems of illuminating the night operations of motor vehicles and to make suitable recommendations for promoting maximum safety and convenience including accessory illuminated signal and traffic aids.

R. P. Teele, Chairman, National Bureau of Standards, Washington 25, D. C.

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L. L. Beltz	H. C. Mead
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D. M. Finch	E. R. Ricker
T. R. Kilgour	V. J. Roper

Roger Sachett

NOMENCLATURE—To define the terms and standards of illumination, and endeavor to obtain uniformity in nomenclature.

S. K. Guth, Chairman, General Electric Co., Nela Park, Cleveland 12, Ohio.

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E. Q. Adams	W. F. Little
L. E. Barbrow	Philip O'Brien
C. L. Cottrell	Priscilla Presbrey

Harris Reinhardt

OFFICE—To study the lighting requirements of office lighting tasks, develop suitable lighting recommendations and report thereon.

G. G. Rae, Chairman, Holophane Co., Inc., 342 Madison Ave., New York 17, N. Y.

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W. S. Fisher	G. P. Wakefield
J. L. Kilpatrick	H. A. Williams
C. W. Macy	R. R. Wylie

R. L. Zahour

PROGRESS—To keep in touch with developments in the art of lighting throughout the world and prepare a yearly review of achievements in the art of illuminating engineering for inclusion in ILLUMINATING ENGINEERING.

M. K. Strang, Chairman, Curtis-AllBrite Lighting, Ltd., 195 Wickstead Ave., Leaside, Toronto 17, Ont., Canada.

H. A. Williams, Vice-Chairman, Rohm & Haas Co., Washington Square, Philadelphia, Pa.

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R. E. Faucett	R. P. Teele
John Gornet	R. R. Tipton
R. E. Hars	R. F. Townsend
A. R. Jaeger	Russell Vichman

QUALITY AND QUANTITY OF ILLUMINATION, RECOMMENDATIONS FOR—To prepare recommendations of illumination levels, brightness limits and brightness relationships in form applicable to practices.

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W. H. Kahler, Vice-Chairman, Westinghouse Electric Corp., 1216 W. 58th St., Cleveland, Ohio.

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R. D. Bradley	L. G. Parks
J. M. Chorlton	G. G. Rae
J. W. Griffith	E. M. Strong

R. P. Teele

RESIDENCE—To study and report on the application of light and lighting in residences; to develop performance recommendations for residence luminaires and to prepare necessary educational aids.

S. R. Shemitz, Chairman, C. S. Mersick Electric Supply Corp., 135 Orange Ave., West Haven, Conn.

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William Blitzer	Jan Reynolds
Rose Coakley	Vito Russo
Myrtle Fahsbender	Mary B. Taepke
Helen Gibbons	H. A. Van Collie
Benjamin Goodman	Mary E. Webber
W. F. Little	N. E. Wernert

ROADWAY—To establish the scientific principles underlying street and highway lighting; to collect data on the results of the application of such principles to actual practice; to prepare such reports thereon as will assist technicians and benefit the public.

Thomas J. Seburn, Chairman, Bureau of Highway Traffic, Strathcona Hall, Yale University, New Haven, Conn.

H. E. Mason, Secretary, City Hall Annex, Room 1032, Philadelphia, Pa.

Jack Alexander	M. A. Lobas
Earl Allgaier	Alexander Lurkis
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*J. D. Blythe	J. F. McGough
P. C. Box	O. W. Meissner
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J. L. Eberly	*B. E. Plowman
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Irving Fishman	F. J. Schmitt
*H. A. Friede	*S. E. Sisco
G. K. Glass	*J. H. Shaw
C. A. B. Halvorson	R. M. Swetland
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William Hawley	William Till
R. M. Hoot	D. A. Toenjes
G. W. Howie	G. A. Trosper
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G. E. Korten	R. R. Wylie
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Handbook

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C. R. Minors

High Speed, Density Highways

P. B. Clark, Chairman, Line Material Industries, 12th & Madison Ave., South Milwaukee, Wis.

*Members only in advisory capacity.

(*Continued on page* 38A)

IES Emblem

The official IES Emblem is available to members in ½-inch, 14-karat gold, screw-back lapel pins at $3.75 each. Background of the emblem is blue for Members, red for Associate Members and white for Fellows. Orders for the lapel pins should be sent to John K. Michel, Membership Secretary, IES Headquarters, 1860 Broadway, New York 23, N. Y.

Wilkes Central High School, Wilkesboro, North Carolina

Not a glimmer of glare in this gym lighting job

INSTALLATION DATA

Abolite HMFAU-2400 fixtures with 750 watt incandescent lamps. Mounting height 22′ with 15′ 6″ x 16′ spacing. Ceiling height: 30′. Average footcandle level: 43.

Architect: Coffey and Olson

Consulting Engineer:
George B. Rottman & Associates

Electrical Contractor:
Ralph Duncan Electric Company

Abolite uplight fixtures shield against glare, wash out ceiling shadows—There are 43 footcandles of light (average) throughout that gymnasium, yet there's practically no glare to bother spectators or players. This easy-on-the-eyes lighting is made possible by the unique design of Abolite fixtures. Notice how both vertical and horizontal surfaces are lighted evenly without any deep shadows and how the light directed upward through the open top of fixtures eliminates sharp contrasts by washing out dark background shadows. 35° lamp shielding virtually eliminates glare.

Abolite's modern air-swept design also reduces maintenance costs. Air circulating through the fixtures sweeps them clean of dulling dust.

Although in this installation Abolite fixtures are used with incandescent lamps, they can also be used with color-improved mercury lamps. There are 18″ and 24″ diameter Alzak aluminum fixtures for use with 400 and 1000 watt mercury and 14″ and 18″ diameter fixtures for 300-500 watt incandescent lamps. *Abolite Lighting Division, The Jones Metal Products Company, West Lafayette, Ohio.*

ABOLITE *Lighting*

THE JONES METAL PRODUCTS COMPANY
West Lafayette, Ohio

(*Continued from page 36A*)

W. H. Edman — C. H. Rex
M. E. Keck — S. E. Sisco
E. E. Paul — R. M. Williston
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Interchange with Foreign Groups

J. W. Young, Chairman, 39 Kingston St., Boston, Mass.

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G. K. Glass — C. H. Rex
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Luminaire Maintenance

H. F. Wall, Chairman, Public Lighting Commission, 174 E. Atwater St., Detroit 26, Mich.

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R. E. Ballard — J. F. McGough
H. S. Beagle — C. R. Minors
R. P. Brotzman — R. J. Palmer
R. S. Bucher — E. Parks
W. H. Dorman — S. E. Sisco
H. A. Friede — W. S. Skove
L. M. Johnson — G. A. Trosper
G. E. Korten — C. E. Waldron
J. W. Young

Parking Area

M. E. Keck, Chairman, Westinghouse Electric Corp., 1216 W. 58th St., Cleveland 1, Ohio.

G. K. Glass — E. H. Schaefer
E. C. Klumb — W. E. Schwannhauser

Photographic Studies

W. E. Hawkins, Chairman, Atlantic City Electric Co., 1600 Pacific Ave., Atlantic City, N. J.

A. W. Fowle — F. J. Schmidt
R. M. Hoot — W. E. Schwannhauser
R. P. Teele

Program and Publicity

W. F. Crosby, Chairman, Corning Glass Works, Corning, N. Y.

*W. B. Hastings — *Robert Kaiser
R. M. Hoot — W. E. Schwannhauser

Research

R. P. Teele, Chairman, National Bureau of Standards, Washington 25, D. C.

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W. B. Elmer — C. H. Rex
D. M. Finch — D. A. Toenjes
M. E. Keck — R. R. Wylie
Peter Young

Roadway Lighting Principles

C. H. Rex, Chairman, General Electric Co., Outdoor Lighting Dept., Hendersonville, N. C.

P. B. Clark — M. E. Keck
W. H. Dorman — G. A. Nagel
W. H. Edman — G. A. Trosper
W. B. Elmer — V. L. Waight
G. W. Howie — H. F. Wall
J. W. Young

Standard Practice

W. H. Edman, Chairman, Holophane Co., Inc., Newark, Ohio.

P. B. Clark — C. H. Rex
W. B. Elmer — D. W. Rowten
C. A. B. Halvorson — G. A. Trosper
M. E. Keck — H. F. Wall
E. C. Klumb — R. C. Wey
G. E. Korten — Henry Wojcik
R. R. Wylie

Traffic Safety

P. C. Box, Chairman, Barton & Associates, Inc., 600 Davis St., Evanston, Ill.

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(Continued on page 44A)

(*Continued from page 43A*)

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(*Continued on page 46A*)

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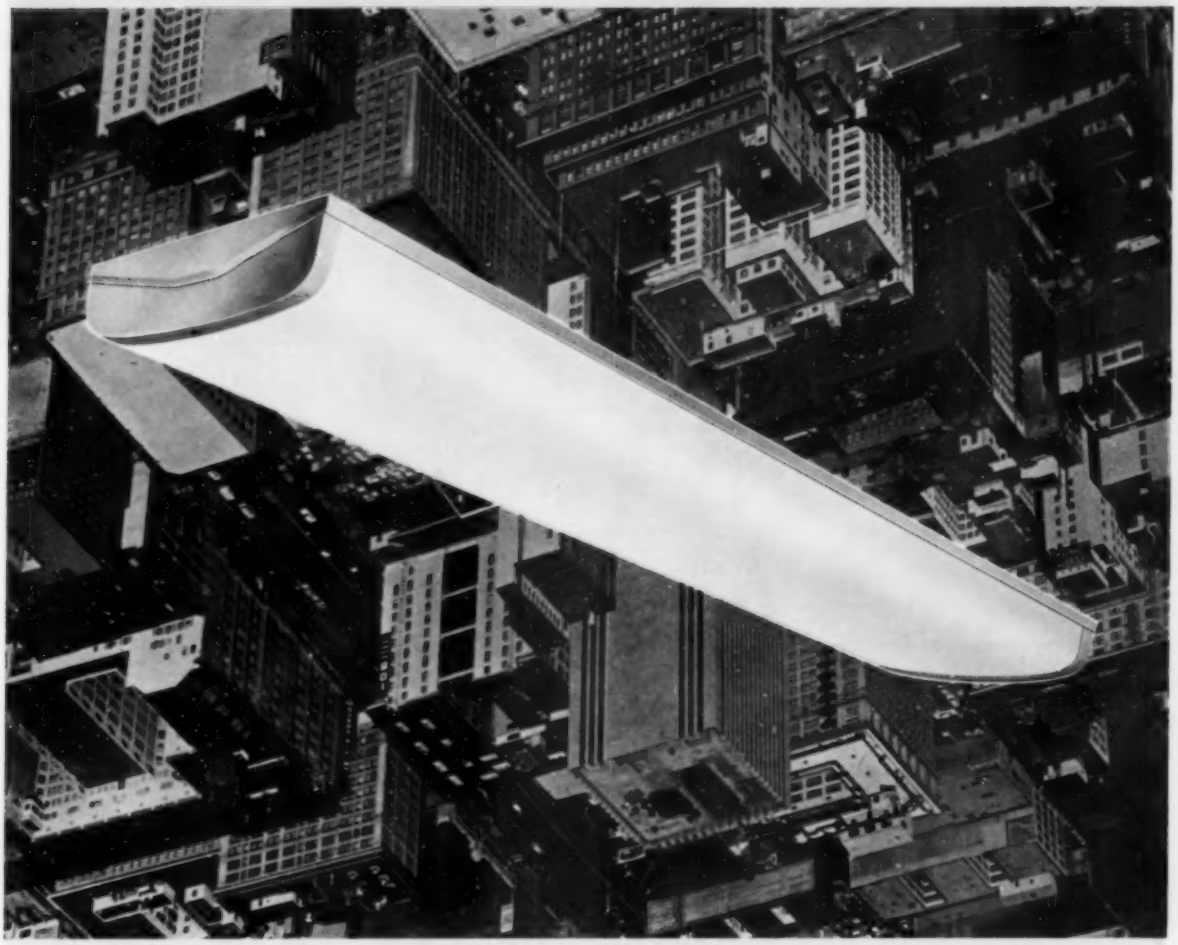

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(Continued from page 44A)

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Region	Date and Place	Chairman
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South Pacific Coast	May 4-5 Sacramento Inn Sacramento, Calif.	M. P. Fenton Smoot-Holman Co. 1331 T St. Sacramento, Calif.
Pacific Northwest	May 8-9 Harrison Hot Springs Harrison, B. C.	E. A. Adams Griffon Sales Ltd. 551 W. 8th Ave. Vancouver, B. C.
Canadian	May 15-16 Queen Elizabeth Hotel Montreal, Que.	J. P. Cristel Shawinigan Water & Power 600 Dorchester St. West Montreal, Que.
Northeastern	June 8-9 Berkeley-Carteret Hotel Asbury Park, N. J.	Bruce J. Jensen Public Service Electric & Gas Co. 80 Park Place Newark, N. J.
Great Lakes	June 19-20 Sheraton-Gibson Hotel Cincinnati, Ohio	H. K. Flint 2926 Debreck Ave. Cincinnati, Ohio

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3. Ruggedized construction. Banner lamps stand up to fiercest punishment. From hard glass shell to solidly welded, multiple-supported innards, they shake off shock, vibration, weather.

4. Life Recording Base—unusual feature saves precious time, annoying paper work by letting you scratch installation date in code right on the base of the lamp.

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(*Continued from page* 28A)

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Thurkauf, Fred, Public Service Electric and Gas Co., Englewood, N. J.

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Rubler, J., Black Light Eastern Corp., Port Washington, N. Y.
Schaetzl, J. B., Central Hudson Gas and Electric Corp., Poughkeepsie, N. Y.
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No Elections

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No Elections

(*Continued on page* 50A)

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For Class 1, Groups C and D; Class 2, Groups E, F, G installations. 60 to 500 W annealed globe.
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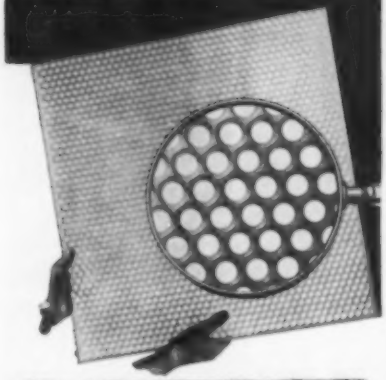

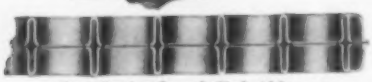

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(*Continued from page 49A*)

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No Elections

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No Elections

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No Elections

MID-SOUTH CHAPTER

No Elections

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(Continued on page 52A)

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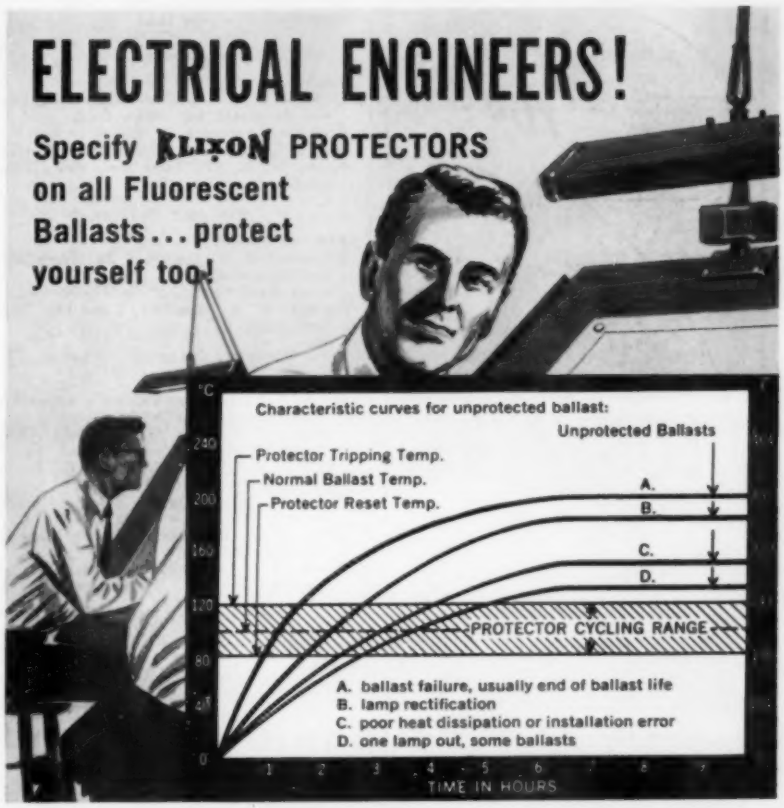


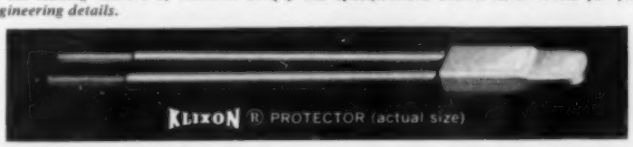
In the installation and operation of fluorescent fixtures (see chart) you can protect your own reputation and give your client important extra benefits at low, low cost . . . simply SPECIFY BALLASTS WITH KLIXON PROTECTORS!

KLIXON® PROTECTORS ASSURE . . .

- Ballasts and fixtures that operate within U/L temperature limits . . . positive protection against overtemperature, overcurrent, or both.
- Cool running installations . . . rapid response against overheat allows correction while contractor is still on job.
- Maximum ballast life . . . external faults can not cause dangerous overheating. When corrected, ballast operates normally again. An internal fault signals need for ballast replacement . . . with protector keeping temperature at a safe level until this is convenient.
- No dripping compound, fires or violent failures at end of ballast life.

These KLIXON benefits are not attainable with fuse protection. Ballasts under some fault conditions draw less than full rated current, still deliver light, but may have a case temperature twice the allowable U/L limit for normal operation. Thus BALLAST OVERHEAT PROTECTION is a TEMPERATURE, not a CURRENT problem.

Ballasts equipped with KLIXON Protectors can be supplied to your fixture manufacturer by all six leading makers of ballasts. Simply use specifications shown here. Write for full engineering details.



USE THIS KLIXON PROTECTION SPECIFICATION

"Ballast shall be thermally protected against overheating by a built-in automatic reset overheat protector sensitive to both winding temperatures and current which will prevent winding temperatures from exceeding 120°C with the exception that the peak temperatures in the first few cycles may exceed this. The protector must allow the winding temperatures to reach 105°C minimum under normal conditions in a 40°C ambient without opening the circuit to the primary winding, and after opening shall not reclose above 85°C. Fixtures must be so designed that ballast coil temperatures shall not exceed the U/L limit of 105°C in a 40°C ambient."

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(*Continued from page* 51A)

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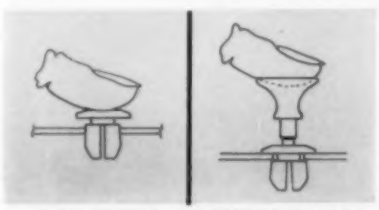

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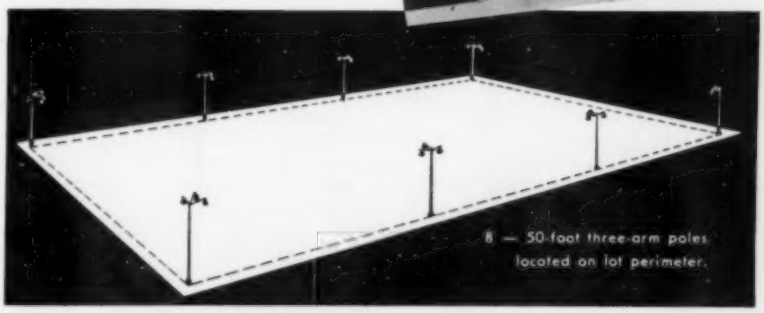

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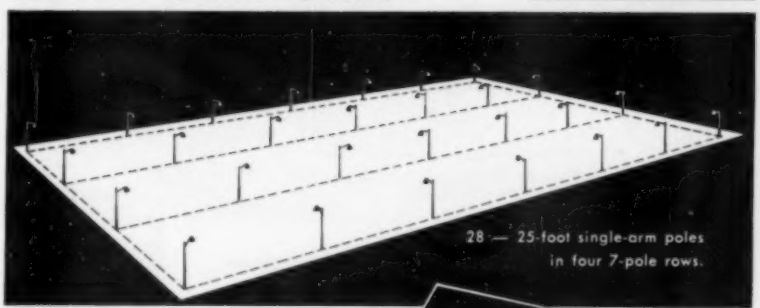

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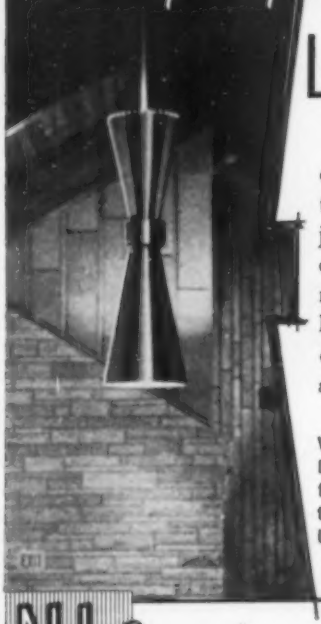

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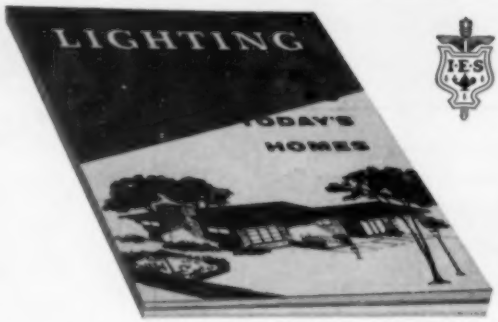

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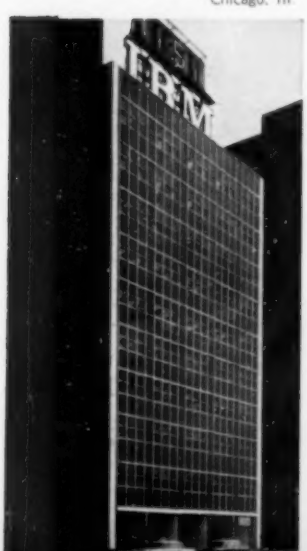

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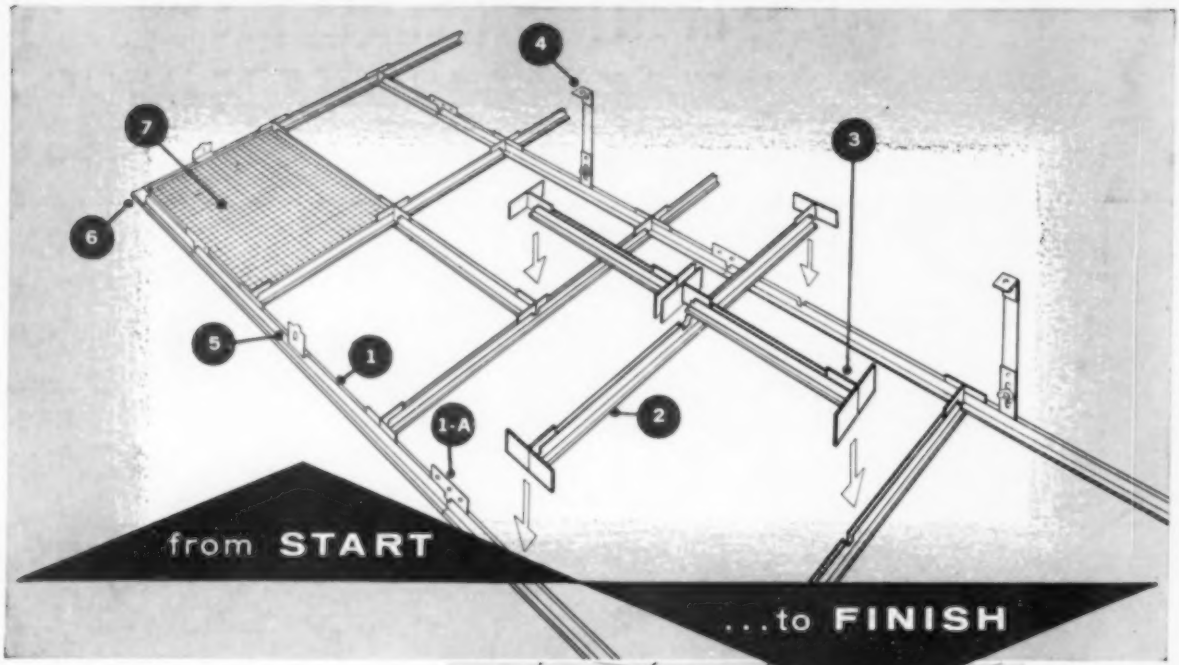

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